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SEAKEEPING INVESTIGATION OF THE U.S. COAST GUARD 270-FT MEDIUM ENDURANCE CLASS CUTTERS: SEA TRIALS ABOARD THE USCGC BEAR (WMEC 901)

by

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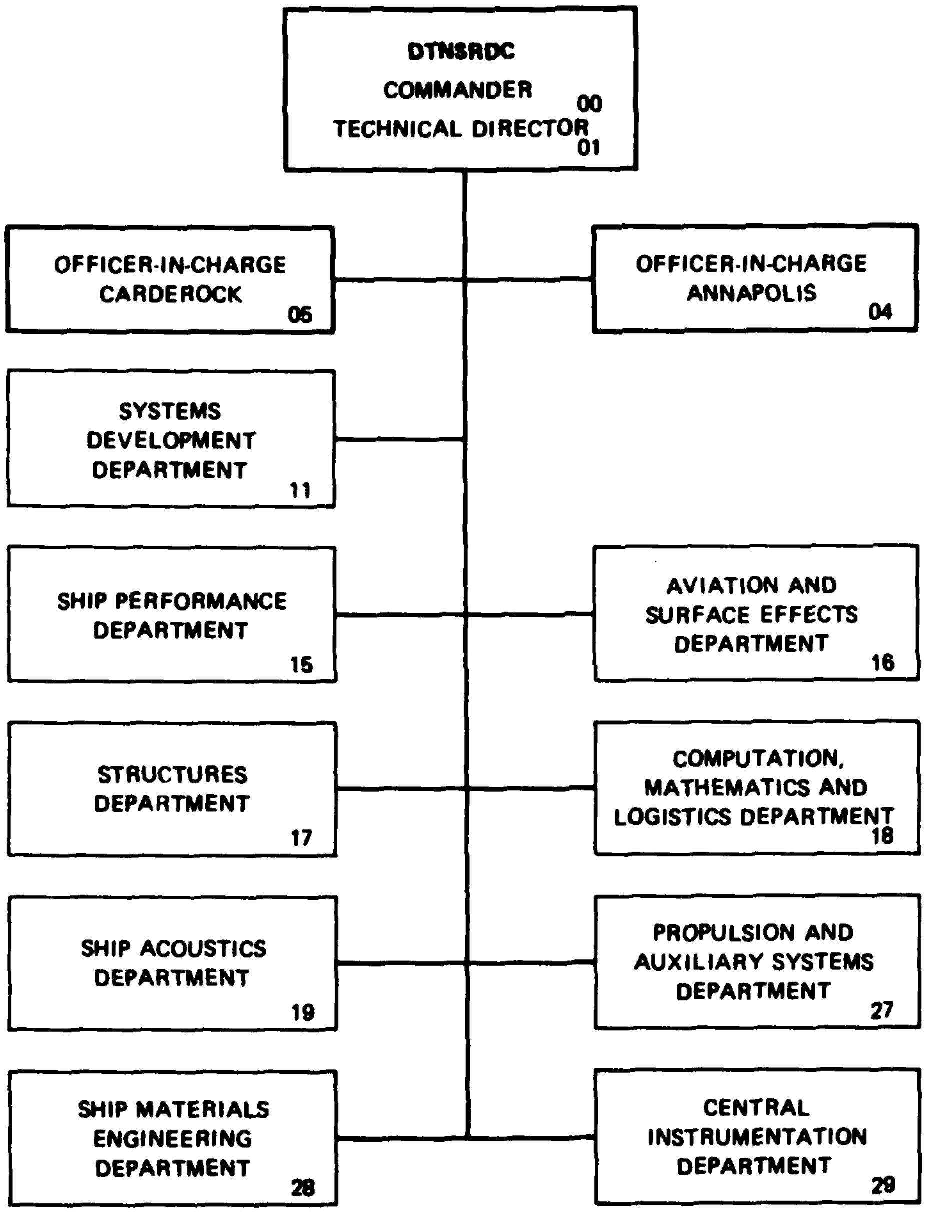

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Two sea trials were conducted aboard the ~~United States Coast Guard~~ Cutter BEAR ~~(WMEC 901) for the purpose of assessing the seakeeping~~ to assess the seakeeping performance characteristics of this vessel class. Time correlated ship motion responses, crew performance data, and anti-roll fin stabilizer measurements were obtained. Trial results indicate excessive wetness due to spray as well as substantial crew performance degradation in relatively mild sea conditions. Design and placement of critical ship

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locations, particularly the pilothouse and Communications Center, ~~have~~ diminished the seakeeping advantages inherent in larger ships. A number of flaws were discovered with the fin stabilization system, including incorrect settings, improper operation, and excessive cavitation. Analytical predictions for the 270-ft cutter, which were made and compared to model test data ~~and~~ were found to be in generally good agreement. Additionally, computer-generated, irregular sea comparisons between the 270-ft WMEC, a 210-ft WMEC, and a 378-ft WHEC were performed. Results indicate that, in general, the 270-ft WMEC has superior or comparable motion characteristics relative to the 210-ft cutter. Predicted roll for the 270-ft cutter is notably greater than for the 210-ft WMEC. Active fin stabilization, which was not modeled, should reduce roll for the 270-ft vessel to levels at or below those predicted for the 210-ft WMEC. Predicted crew performance degradation substantiates the impact of ship location on critical shipboard functions. A range of recommendations for improving the seakeeping performance of the 270-ft Class are made as well as a recommendation for a side-by-side sea trial for a 270-ft and a 210-ft cutter in order to validate the findings presented herein.

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ABSTRACT

Two sea trials were conducted aboard the United States Coast Guard Cutter BEAR (WMEC 901) for the purpose of assessing the seakeeping performance characteristics of this vessel class. Time correlated ship motion responses, crew performance data, and anti-roll fin stabilizer measurements were obtained. Trial results indicate excessive wetness due to spray as well as substantial crew performance degradation in relatively mild sea conditions. Design and placement of critical ship locations, particularly the pilothouse and Communications Center, have diminished the seakeeping advantages inherent in larger ships. A number of flaws were discovered with the fin stabilization system, including incorrect settings, improper operation, and excessive cavitation. Analytical predictions for the 270-ft cutter were made and compared to model test data, and were found to be in generally good agreement. Additionally, computer-generated, irregular sea comparisons between the 270-ft WMEC, a 210-ft WMEC, and a 378-ft WHEC were performed. Results indicate that, in general, the 270-ft WMEC has superior or comparable motion characteristics relative to the 210-ft cutter. Predicted roll for the 270-ft cutter is notably greater than for the 210-ft WMEC. Active fin stabilization, which was not modeled, should reduce roll for the 270-ft vessel to levels at or below those predicted for the 210-ft WMEC. Predicted crew performance degradation substantiates the impact of ship location on critical shipboard functions. A range of recommendations for improving the seakeeping performance of the 270-ft Class are made as well as a recommendation for a side-by-side sea trial for a 270-ft and a 210-ft cutter in order to validate the findings presented herein.

ADMINISTRATIVE INFORMATION

This investigation was authorized by the United States Coast Guard under MIPR Z70099-4-00758 and is identified at David Taylor Naval Ship Research and Development Center as Work Unit 1561-047.

INTRODUCTION

David W. Taylor Naval Ship R&D Center (DTNSRDC) was requested to conduct full-scale sea trials aboard the United States Coast Guard (USCG) Cutter BEAR (WMEC 901) in March-April. The objective of the trials was to evaluate the seakeeping characteristics of the new USCG 270-ft Medium Endurance Class Cutter. Limited at-sea experience with the BEAR, the first of the class, indicated that ship motions were more severe than originally expected. In particular, vertical motions (pitch and

vertical acceleration) as well as the frequency of deck wetness and the shipping of green water was reported to be well above the predicted levels[1*]. Damage to the forecastle and forward gun mount had been sustained on the ship's transit from San Francisco Bay to the East Coast. Several contributing factors were cited, including the ship's trim (i.e., bow down) and the common occurrence of random, large waves in the vicinity where the damage was incurred. Nevertheless, the perception of the vessel as a poor seakeeper, specifically characterized as worse than the smaller USCG 210-ft WMEC Class, prompted the investigation to document the ship motions in the actual sea environment.

The first sea trial, which was conducted in March 1984 off the Virginia Coast, was to evaluate the ship as a complete system: that is, to document the ship motions, the ship motion effects on ship personnel and the effect on anti-roll fin stabilizers on ship motions. This "system evaluation" was accomplished by outfitting the vessel at the center of gravity and at five ship locations with electronic devices, while soliciting from selected crew members an assessment of their physical and mental condition through the use of a questionnaire. Additionally, the fin stabilizer system was instrumented to measure fin command signals and fin angular responses.

Wave height measurements were to be taken with a wave buoy which had been secured to the fantail. Poor weather conditions, which caused the fantail to be awash, and thus unsafe, as well as minor damage to the buoy, prevented the launch and recovery of the wave buoy on the first two test days. Later, wave measurements could not be performed as the BEAR became involved in a dedicated search pattern.

This lack of wave data gave impetus to a second sea trial, performed off the North Carolina coast in April 1984. It was recommended by DTNSRDC prior to this second trial that a 210-ft WMEC be scheduled for a side-by-side investigation. This would allow an accurate comparison of the motion responses of the two vessels in an identical seaway. Unfortunately, a 210-ft WMEC could not be dedicated within the time and schedule constraints of the second sea trial. The instrumentation package aboard the BEAR was reduced to include the center of gravity and a single point location, and no questionnaires were issued. Again, fin responses were measured. A wave buoy supplied by the USCG was used to measure wave height.

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*A complete listing of references is given on page 67.

Since no full-scale side-by-side effort could be performed, an analytical study was carried out using the Navy Standard Ship Motion Program (SMP)[2]. Both a 210-ft and the 270-ft WMEC's were computer modeled, identical ship locations identified, and input and identical seaways were investigated. The relative merits of the two vessels and the point locations determined from this study are presented in this report.

PROCEDURE AND METHODS

FULL-SCALE TRIALS

Prior to seakeeping trials aboard the BEAR, an agenda was proposed outlining how the experiment was to be conducted. Three major areas of measurement were to be investigated: ship motions, crew performance, and fin stabilizer performa· This, it was felt, would present an overall assessment of the ship as a sys' , To that end, instrumentation was placed at three "habitation" areas, two ship ›- system locations and at a point near the center of gravity. The latter wou ' .o- vide the stabilized, earth-referenced surge, sway, heave, roll, and pitch motions. Hard-mounted accelerometers in the other locations would measure ship-referenced lateral and vertical accelerations which will henceforth be referred to as transverse and normal accelerations, respectively. These transverse and normal accelerations are direct measurements of the ship motion-induced forces experienced by shipboard systems and crew.

Crew performance measurements were to be made by selected crew members using the DTNSRDC Performance Assessment Questionnaire II[3]. This evaluation document contained a variety of questions for individual crewmen, department heads, and the commanding officer aimed at ascertaining motion- and/or seasickness-induced impairment. Additionally, two areas of the ship, the Communications Support Center (CSC) and the Communications Center (Radio Room), were monitored and evaluated by the Naval Biodynamics Laboratory (NBDL) as tasked by DTNSRDC. Full details of the Performance Assessment Questionnaire and the NBDL study are contained in Appendix A.

To obtain meaningful seakeeping data, a variety of headings, speeds, and sea states is desirable. An octagonal course pattern was determined to best meet these measurement requirements. Each octagonal pattern would be conducted for a constant ship speed. Each "leg" of the octagon would be comprised of two 20-minute segments during which time the ship would maintain a steady course. Each segment

corresponded to a fins-on or a fins-off condition. At the end of 40 minutes the ship would turn 45 degrees to a new course and obtain measurements for another 40-minute time period (see Figure 1a).

Originally, it had been planned to conduct two octagonal patterns per day at a high and an intermediate speed. Each octagon would be preceded by a half-hour wave height collection run. It became quickly apparent that due to the length of time involved to execute a complete octagon as well as the fatigue factor for both crew and test personnel, only one test pattern could reasonably be performed in a single day. Furthermore, no wave height measurements were conducted for the first sea trial. A practice wave height run performed the first day upon arriving at the operations area met with very limited success. The seaway was building and stationkeeping, in order to prevent towing the wave buoy, was extremely difficult. The following two full test days produced seas and ship motion/wetness conditions considered too severe to launch the buoy. Moreover, minor damage had been sustained to the buoy by gasoline cans which had broken loose in the rough weather encountered the first night at sea. Seaway estimates were, therefore, visually made from the bridge for the first sea trial.

The high speed octagon was to be run at the maximum possible speed for each leg. Specifically, it was intended that both the limiting speed and the physical cause for any speed limitation be established for each course during the pattern, and for each of the seaways encountered. It is considered that the physical cause for speed limitation may be hydrodynamic in nature (such as slamming, excessive deck wetness, pitch, vertical acceleration, etc.) or direct consequences of these hydrodynamic factors (such as actual/potential ship system failure(s), human factors, etc.).

Placement of the electronic equipment used to measure the ship motions became important in the context of evaluation of the ship and crew as a complete system. Four specific ship areas were chosen to place pairs of force-balanced accelerometers in order to measure transverse and normal accelerations: the crew's mess, the vestibule between the pilothouse and CSC, the helicopter flight deck, and the Communications Center. A Ship Motion Recorder (SMR) was placed forward beneath the gun mount and measured both transverse and normal accelerations as well as roll and pitch. To provide earth-referenced motion measurements, a gyroscopic "stable table" was located near the center of gravity in the engine room. Table 1 provides the precise locations of these measuring devices.

Additional channels which were recorded include helm command, rudder angle, ship course, ship speed (without calibration), fin command, port and starboard fin angles, fin Auxiliary Sensor Unit (ASU) roll, and ship yaw. All data was recorded using a Hewlett-Packard 9845 computer system. Analog tape recorders and an analog strip chart were used to record selective channels. All amplification and recording equipment was located in the machine workshop on the main deck. The Wave Crest wave buoy supplied for the first sea trial was secured to the fantail.

As mentioned earlier, each leg of the octagonal course pattern consisted of a fins-on and fins-off segment. This method was to provide a comparison of ship roll at identical headings and speeds for the active and passive anti-roll fin stabilizers. A Sperry Marine representative was available prior to the trial for initial adjustment of the system and hook-up to DTNSRDC recording gear. Furthermore, a Sperry Marine representative rode the BEAR during the first sea trial.

The second sea trial, conducted in April 1984, measured a smaller number of data channels. Center of gravity motions and tranverse/normal accelerations at the CSC/pilothouse location were recorded as were yaw, ship's course and speed (calibrated), helm and rudder angle, fin command, fin angles, and wave height.

Secured to the fantail from which launch and recovery were performed was a Datawell wave buoy supplied by USCG. Because wave height was to be measured with the wave buoy floating free (i.e., not tethered to the ship), a different course pattern was utilized. Eight different headings with respect to the seaway were performed with the fins-on/fins-off segments, as in the first sea trial. However, to accommodate the range of the telemetered wave data constantly being beamed to ship and to facilitate tracking/locating the buoy, a crisscross pattern shown in Figure 1b was conducted.

ANALYTICAL

Since a full-scale, side-by-side comparison of the 270-ft WMEC with a 210-ft WMEC could not be arranged, an analytical study of both vessels in identical seaways was conducted using SMP. This computer program predicts frequency-domain ship responses in regular and irregular seas for ship headings around the clock in 15-degree increments.

The first step of this analysis was to run SMP for the 270-ft WMEC in the model test condition and compare the Response Amplitude Operators (RAO's) with those measured during the model tests of Reference 1. This would confirm the accuracy of

the computer input as well as validate the model test results. This analytical comparison was in fact previously performed[4] using a computer program on which SMP is based. By establishing a basic confidence level in the computer description of the 270-ft WMEC in the model test configuration, the input could be adjusted to full-scale and be accurately compared to a full-scale 210-ft WMEC.

Sea spectra chosen for the comparison were Bretschneider two-parameter sea spectra[5] of significant wave heights approximating those encountered during the two sea trials on board BEAR. A range of modal wave periods for each wave height was investigated.

Figure 2 presents outboard profiles of the 270-ft and 210-ft WMEC's to scale and Figure 3 presents the computer-generated underwater hull configurations. The ship particulars are presented for both vessels in Table 2.

For the prediction work of the two WMEC's, comparable ship locations measured on the BEAR trials were identified as points of interest on both vessels. Table 3 details these point locations for the 210-ft WMEC. The 270-ft WMEC measured/analytical points are presented in Table 1.

RESULTS AND DISCUSSION

SHIP PERFORMANCE - SEA TRIALS

The RMS and maximum ship responses as measured during both sea trials are presented in Tables 4 through 8. Tables 4-7 represent the first sea trial while Table 8 summarizes the results of the second sea trial. Several important points need to be stated concerning these tables. First, each table represents a particular day of testing and is designated in the table title. Second, the fin condition refers to whether the fin stabilizer system was in the active or a passive mode, indicated by "on" or "off", respectively. A change in the fin rate was made and noted in Table 6, and the maximum fin angle excursion was reduced from ±24 degrees to ±20 degrees as noted in Table 7 and Table 8. Third, ship speed is in knots as observed from the bridge. More than one speed indicates a reduction in speed during the run as ordered by the OOD. Fourth, observed wave height in feet is the estimated double amplitude (peak-to-trough) wave height recorded by the trials director. Finally, missing data points as indicated by a "-" denotes lost values due to equipment malfunction, power loss, bad data, etc. In the case of Table 8, data was acquired only for the one point location, the pilothouse/CSC area.

Also in Table 8, three wave height runs are indicated (Runs 71, 75, and 81). Data from these runs were spectrally analysed and the results are tabulated below:

Run	Computed Significant Wave Height	Computed Dominant Wave Period
71	12.4 ft (3.8m)	9.1 sec
75	9.3 ft (2.8m)	8.5 sec
81	9.7 ft (3.0m)	9.5 sec

These results are in direct conflict with observed wave heights recorded by the trials director as well as the ship's log. The discrepancy is nearly a factor of two too large. No post-calibration was performed since the Datawell buoy, which was used to record wave height, was supplied by the USCG. Inquiries made after the trial indicate that the calibration used (i.e., 1 meter/volt) is correct. Only two other possible explanations exist: (1) an incorrect amplifier gain used at the time the data was recorded, or (2) the buoy sensors are out of calibration. The latter explanation is considered unlikely, particularly to the degree of error observed. More likely is the first explanation since a gain error could, in fact, double the amplitudes being recorded. Assuming this to be the case, Figure 4 presents the "corrected" wave spectra for wave height runs 71, 75, and 81 along with their corresponding significant wave heights, $(\bar{\zeta})_{1/3}$, and periods, T_0.

As previously noted, deck wetness continues to be an area of concern for the 270-ft WMEC. Observations from the bridge during the first sea trial, and as documented on film during the second sea trial, indicate that the vast majority of wetness is due to spray. At almost any relative heading to the predominant sea with perhaps the exception of following seas, the BEAR encountered mild to excessive wetness on the forecastle and bridge due primarily to spray. Even in quartering waves, the ship would occasionally take spray over the deck. From time to time, moreover, white water, and rarely green water, was observed on the forecastle. Particularly severe were head and bow sea conditions, where an occasional slam would occur. Noted for Run 26, a starboard bow condition, was that the forward deck was awash 75 percent of the time. Port bow seas of Runs 28 and 29 produced large rolls and frequent spray up to the bridge level. The most severe situation

during the first sea trial occurred after turning to the head sea heading in Run 36. After several minutes into this run, a severe slam and water on the forecastle caused damage to the forward stanchions and lifelines as well as other minor damage. The commanding officer immediately reduced speed from 16 (RPM setting for 19 knots) to 15 knots, and later to 12 knots to reduce water over the bow and slamming. The intensity of this run is documented in Table 5. Note the high vertical accelerations recorded at the center of gravity (.76 G's), the pilothouse (.68 G's), the Communications Center (~.8 G's), and particularly the gun mount area (1.07 G's). Even at the lower speed at the same heading during Run 37, white water and spray continued occasionally.

Run 36 represented a genuine speed-limiting situation. The severity of this set of conditions, though perhaps overstated at the time of occurrence, did result in damage due to the shipping of green water; and there is no doubt that continued, and perhaps more serious, deleterious effects could have been expected had the speed and course remained constant.

SHIP PERFORMANCE - ANALYTICAL

An analytical study using SMP was conducted for the 270-ft WMEC because of two specific concerns: interpretation of model test results and the perception that the 210-ft WMEC is a better seakeeper. To address the former, a computer simulation of the model test conditions was performed and the results presented in Appendix B. The response amplitude operator (RAO) comparisons illustrate good agreement for the vertical motions of heave and pitch and for relative motion at Station 0 (Figure B-1 through B-3). In Figure B-4, vertical acceleration at Station 14 (approximate location of the helicopter flight deck), however, does not show the same adequate comparison. It should be noted that, although model tests provide a controlled environment and specific sea spectra, precise duplication of those conditions cannot always be achieved via computer modeling. Table B-1 compares the significant single amplitude responses of the model test and SMP data. As the second footnote indicates, the wave spectrum of the model test could not be accurately computer modeled. Therefore, a range of values for the 5-foot significant wave height case corresponding to the spectrum's broad frequency range are presented. The SMP vertical acceleration at Station 14 demonstrates the same overprediction prevalent in the RAO data of Figure B-4.

The concern expressed by some that the motions and seakeeping characteristics of the 270-ft WMEC are no better, or even worse, than the 210-ft WMEC prompted the request by DTNSRDC to perform a second sea trial with both vessels. As stated earlier, this could not be scheduled. However, an analytical comparison using SMP was conducted and selected results are presented in Figures 5-11. The seaway considered for the comparison is shortcrested with a 13-foot significant wave height and a 9-second modal wave period. Figure 5 compares roll and pitch and Figure 6 compares the center of gravity motions of sway acceleration and heave acceleration. Noteable in this group is the superiority of the 270-ft WMEC for all motions except roll. It is believed, however, that the magnitude of roll reduction due to proper active fin stabilization, which was not computer-modeled, should reduce these roll values to below those of the 210-ft WMEC.

The lateral and vertical accelerations for the five point locations shown in Tables 1 (270-ft WMEC) and 3 (210-ft WMEC) are presented in Figures 7-11. Of special note is that these accelerations are, as are all frequency domain motions, referenced to the earth system. This is very important in the case of lateral acceleration since, in the ship reference system (transverse acceleration), a sizable increase can be expected due to the additional gravity component contributed by roll[6]. This transverse acceleration is much larger than the earth-referenced lateral acceleration even when roll motions are relatively small. Therefore, caution should be exercised in drawing conclusions using this lateral acceleration data. For instance, predicted personnel performance, particularly the number of interruptions a crew member may experience in order to maintain his balance, is a function of the transverse accelerations.

Point 1, the crew's mess, is compared in Figure 7. The 270-ft WMEC shows lower motion levels at nearly all headings and, in the case of vertical acceleration, substantial differences exist at head and near-head sea conditions. Figure 8 shows pretty much the same trends for the helicopter flight deck, Point 3. The lateral accelerations appear very comparable while the vertical accelerations of the 270-ft WMEC at all headings is equal to or less than the vertical acceleration of the 210-ft WMEC. Point 5, the gun mount, is compared in Figure 9. Lateral acceleration is higher for the 270-ft WMEC and vertical acceleration is comparable to the 210-ft WMEC. These results need to be tempered by the fact that the 270-ft ship's "gun mount" location is really forward of the gun mount due to the placement of the trials instrumentation. Table 1 clearly illustrates this fact.

Figure 10 presents the comparison of lateral and vertical accelerations at the pilothouse locations. Lateral accelerations at all headings are slightly higher for the 270-ft vessel and vertical accelerations of both ships are very close in magnitude. This result is not completely surprising when the location of the pilothouse for the 270-ft WMEC versus that of the 210-ft WMEC are compared. Note in Figure 2 how much farther forward from midships the pilothouse of the 270-ft WMEC is than the 210-ft ship. The vertical motion at any point on the ship is calculated using

$$L_V = z - x^*\theta + y^*\phi \qquad (1)$$

where L_V is the vertical motion; z, θ, and ϕ correspond to heave, pitch, and roll, respectively; and x^* and y^* are the x- and y-distances from the center of gravity. Since the center of gravity lies very near midships for both vessels (see Tables 1 and 3), the 270' WMEC "sees" more vertical motion at the pilothouse than if it were located in a more central (midships) area as is the pilothouse of the 210-ft WMEC. In fact, the analytical point location chosen for the pilothouse of the 270-ft ship corresponds to a half-way point between the bridge and CSC. This was the location of the instrumentation package used for the sea trials aboard the BEAR. If the actual pilothouse location (which is farther from the center of gravity) had been used, the 270-ft WMEC might well exceed the vertical acceleration values of the 210-ft WMEC shown in Figure 10.

A similar situation exists for the Communications Center locations. Figure 11 presents the lateral and vertical accelerations and, again, the magnitudes of motions for both vessels are very close. Note that the vertical locations for this area on each ship are quite different (Tables 1 and 3). The vertical accelerations, however, are really affected only by the longitudinal and lateral distance from the center of gravity (Equation 1).

It will be recalled that a perception exists that the 270-ft Class cutter rides like or worse than the 210-ft WMEC. Moreover, the Communications Center and CSC were identified as areas of high motion sickness incidence and crew degradation. The data presented in Figures 10 and 11 substantiates, in part, this perception. Motion sickness incidence (MSI) is a function of vertical acceleration and it associated period[7]. The magnitudes of vertical acceleration in these areas (and the pilothouse) are so similar as to present an impression to the rider that he is on

the smaller vessel. In fact, the advantages of building a larger ship to gain better seakeeping qualities may have been sacrificed, at least in the habitation considerations, by placing the critical compartments so far forward. To illustrate this point, a comparison of each location from the Forward Perpendicualr (F.P.) in terms of percentage of the Lpp is presented below:

Point	Location	270' WMEC	210' WMEC
1	Crew's Mess	57%	66%
2	Pilothouse	27%	35%
3	Helo Deck	69%	69%
4	Comm. Center	21%	31%
5	Gun Mount	6%	15%

Fifty percent represents midships and, thus, a location very near the center of gravity. Note that for the two locations on the 270-ft WMEC demonstrating superior motion characteristics (i.e., Points 1 and 3), the relative location to midships is equal to or better than the 210-ft WMEC. However, for Points 2 and 4, the relative distance from the center of gravity is greater for the 270-ft cutter and thus helps to explain the poor motion qualities and unfavorable ride characteristics of these locations.

To underscore this argument, Figure 12 compares a third ship, the USCG 378-ft WHEC, to both the 210-ft and 270-ft WMEC's for pitch, vertical acceleration at the pilothouse and vertical acceleration at the Communications Center. For pitch motion in Figure 12, note that the 270-ft WMEC falls not unexpectedly in between the 210-ft and 378-ft ships. But for the vertical accelerations, particularly in the Communications Center, the WHEC falls well below both the 270-ft and 210-ft vessels. Not surprisingly, the percentages of Lpp that correspond to the pilothouse and the Communications Center on the WHEC are nearer to the 50 percent "midship location" than the 270-ft WMEC; that is, 31 percent for the pilothouse and 47 percent for the Communications Center.

Since rideability will have a major impact on perception of a vessel's seakeeping qualities, an additional analytical comparison of the 270-ft and 210-ft WMEC's was done for the incidence of motion-induced interruptions (MII) and motion-

sickness incidence (MSI). This will be discussed in a later section entitled CREW PERFORMANCE - ANALYTICAL.

Deck wetness, its frequency of occurrence, and its severity (i.e., green water vs. spray) constitutes a major area of concern for the 270-ft WMEC. As discussed earlier, experience on the BEAR prior to and during the seakeeping trials had shown the decks to be awash in relatively mild seas, and the occasional shipping of green water to cause damage in the forward deck areas, particularly the forward stanchions and lifelines. However, observations made during both sea trials confirm that the primary cause of deck wetness is spray (see SHIP PERFORMANCE - SEA TRIALS). This observation is, in part, corroborated by the predicted comparison of the 270-ft WMEC with the 210-ft WMEC. Below is the computed number of occurrences of slamming, deck wetness (green water) at Stations 0 and 2, and the emergence of the forefoot of each vessel every hour in a Sea State 5. Ship speed is 15 knots, significant wave height is 13 feet (4 meters), modal wave period is 9 seconds, and the relative heading is head seas:

	Slamming (Station 3)	Deck Wetness (Station 0)	Deck Wetness (Station 2)	Forefoot Emergence
270-ft WMEC	14	19	6	171
210-ft WMEC	94	33	10	294

As shown, the 270-ft WMEC is far superior to the 210-ft vessel in all cases.

Furthermore, the predicted occurrence of submergence of the forward deck area for the 270-ft cutter is not very large for this size vessel in a high sea state. For instance, an identical 13-foot, 9-second seaway produced 24 occurrences of deck wetness per hour at Station 0, and 12 occurrences per hour at Station 2 for the larger 378-ft WHEC.

It is important to remember that the prediction of relative motion parameters such as slamming and deck wetness are a direct function of draft, freeboard, sinkage and trim of the vessel, as well as the vertical motion at each point with respect to the waves and the period of the waves. Uncertainties exist in the theory which computes these relative motion parameters. Likewise, model experiments are constrained by imprecise scaling factors. That is, no model experiment

could have predicted the type of wetness that the 270-ft WMEC primarily exhibits since spray does not scale.

CREW PERFORMANCE - SEA TRIALS

The results of the Performance Assessment Questionnaire II, as described in Appendix A, will be detailed in this section. It is to be recognized that a measurement tool such as this questionnaire is only as accurate as the subjective perceptions of the respondents. Data acquired by this method, especially if it involves the evaluation of others as in the case of the department heads' assessments, are necessarily opinion-based. Moreover, it is common during the analysis process to encounter missing or incomplete information. This results in varying totals and percentages across test conditions, and often makes definitive interpretation of the data difficult or impossible. However, though measurement controls may be imperfect, it is believed that the attempted evaluation of performance levels of actual crew tasks in a realistic seaway has significant merit.

The results of the department head assessments are summarized in Tables 9 and 10 for the first two test days, March 6 and 7, respectively. These tabulations present the total number of crew members evaluated, the number of crew affected by seasickness, and an overall percentage of impaired performance for the total number of crew members evaluated. This last column is a summation of the department heads' estimation of the percent performance degradation due to all causes for crew members covered in the assessment. To this extent, it can be considered an overall measurement of shipboard task performance capability.

Figures 13 and 14 present the perceived causes of crew impairment and the degree of impairment as determined by each department head on March 6 and 7, respectively. More than one cause was often cited as reason for performance degradation, such as excessive ship motions and seasickness combined. This type of multiple response is reflected in these figures. Note that ship motions is the primary cause of impairment for almost all conditions, and that frequently this condition is worse for the active fin cases. Had the fins been working correctly, a reduction in motion interference in the "fins-on" mode should have consistently been reflected in these figures. Unfortunately, because of deficiencies with the BEAR fins as tested,[8] the impact in terms of crew performance of proper roll stabilization cannot be illustrated.

A review of the questionnaire's individual assessment section revealed four locations on the vessel occupied by a number of the respondents throughout the first two test days. Figures 15 and 16 present this data for each run in terms of where they were and if any degree of impairment was experienced. The information provided in these figures does not necessarily reflect the total number of people (or their impairment) in the ship spaces illustrated. Further, the degree of impairment shown may range from only "slight" to totally "incapacitated." It is interesting to note the large number of respondents always present in the mess/galley/wardroom area. This area's popularity may be attributed not only to off-duty socializing, but also the significant ride comfort afforded by the midship area of the vessel.

Finally, the comments and observations of the commanding officer (CO) from the first two test days of the March trial are summarized in Table 11. Listed are the conditions of each run and a tabulation of the captain's comments as detailed on his questionnare. Each pair of runs for a single relative heading corresponds to a fins-on and fins-off segment of the octagon (e.g., Run 8 is with fins on and Run 9 is with fins off for starboard quartering seas). Excessive motion values in degrees are the CO's estimates based on ship's inclinometer readings. Actual maximum motion amplitudes are tabulated in Tables 4 and 5 for these two days. Crew performance problems, as indicated on this table, represent any mention by the CO of apparent or potential crew impairment due to excessive ship motions, fatigue, or seasickness. If ship speed was limited, a reason for such a limitation, as denoted by the CO, is given as a footnote. The CO's assessment of whether or not to maintain the speed and course combination of each run is also given. In some cases, speed was reduced, as indicated. In several cases, the decision to slow or alter course would have been made under routine patrol conditions, but course and speed were continued for this investigation. It was the judgment of the CO that, given a life-or-death situation, none of the conditions encountered during the sea trial were severe enough to change the speed or course.

SEA TRIAL OBSERVATIONS

Several of the comments that the CO made on his questionnaire are of particular interest. For example, an area of concern cited a number of times was the continually wet decks on the bridge. During large motion cycles, a genuine injury potential exists, particularly with respect to the high voltage equipment on the

bridge. Most of the wetness in the bridge came from excessive spray over the forward section of the ship, entering through windows and doors. Lack of hand holds both for the helmsman and in the vestibule area aft of the bridge was mentioned as a problem. The first resulted in steering difficulty, particularly during large rolls, and the latter poses a personnel hazard in heavy seas. The CO also complained a number of times of excessive noise on the mess deck, even at reduced ship speeds. During quartering and following sea runs, the CO stated that the yawing of the vessel appeared to be less of a problem than on the smaller 210-ft WMEC. The CO commented on the problems of living and working in his stateroom both on his questionnaire and during the sea trial. This is not surprising since his stateroom is directly below the pilothouse; that is, high and up forward where the effects of ship motions are most severe.

Finally, a misconception has occurred due to the definition in terms relating to deck wetness. On several occasions, descriptors such as "white water" and "green water" were used to indicate wetness conditions. It is understood in the ship seakeeping R&D and hull design community that "green water" means that water on the deck has a density that is equal to the density of ocean water. In other words, water on the deck consists entirely of water and not, as is most common, a combination of air and water usually referred to as "white water" or spray. Figure 17 illustrates the occurrence of white water and spray on board a 210-ft WMEC in a series of three photographs. Observations from the first trial and video tapes of the second trial substantiate the earlier discussion (SHIP PERFORMANCE - SEA TRIALS) that rarely did green water occur on the deck of the BEAR. During Run 36 minor damage was done to the BEAR as detailed in a message by the CO. In that message, reference to green water up to the bridge level was made. Observations from the bridge at the time of the occurrence by the DTNSRDC trials team member responsible for noting trial conditions indicate that green water was shipped on the forecastle up to and enveloping the gun and gun mount. The resulting dispersion of the water in the form of white water and spray was observed up ot the bridge level. It is believed that green water of the magnitude described by the DTNSRDC trials team member should have incurred more damage than actually resulted. Most assuredly, green water was not taken up to the bridge level or much more substantial damage would have been the result. With the exception of Run 36, the shipping of green water was confined to wave overtopping, extending only to the first few feet of the deck.

CREW PERFORMANCE - ANALYTICAL

Analytical comparisons of ship motions have been presented for the 270-ft WMEC's at various locations. These motions have a corresponding effect on crew performance in terms of motion-induced interruptions (MII) and motion sickness incidence (MSI).

The former refers to the frequency of ship motion conditions which causes a crew member to lose his balance, or have to "hang on." It is a measure of the severity of the crew's inability to perform a wide variety of small and large manual tasks. MSI is a measure of the crew's impairment due to seasickness. MII are computed using lateral and vertical accelerations as well as roll to determine transverse and normal accelerations that cause tipping over, sliding, or lifting off the deck. MSI is a function of vertical acceleration and its related period as developed and defined in Reference 7.

Using the ship motion data base computed from SMP, the relative severity of performance degradation due to MII and MSI was predicted and compared for both the 270-ft and 210-ft cutters. Figure 18 presents a sample comparison of MII for shortcrested seaways of 13 feet (4 meters) significant wave height and 9 and 11-second modal wave periods. The four locations shown are those corresponding to Points 1-4 from Tables 1 and 3. Likewise, MSI for the same locations are compared in Figure 19 for the same seaway conditions.

Two important points should be made concerning these analytical comparisons. First, the MII calculations are dependent on roll to compute the transverse accelerations. Lateral accelerations (that is, without roll) tend to be small compared to vertical accelerations. However, with the effect of a gravity component due to roll, transverse accelerations become sizable. Roll for the 270-ft WMEC is overpredicted, as stated earlier, because roll stabilization due to active fins is not currently predicted in SMP. Therefore, the comparisons of this vessel with the 210-ft WMEC must necessarily be for the passive (or fins-off) case, and the MII must be considered conservative in magnitude (i.e, larger than expected under the normal, fins-on condition).

Secondly, it has been shown that trends in the predicted occurrence of motion sickness incidence appear reliable, though the MSI percentages tend to underpredict actual observed seasickness incidence[3]. Since predicted MSI is dependent on the idealized seaway of known frequency content in SMP, it is not unreasonable to expect higher MSI at sea, where the vertical acceleration frequency range may be

broader and more variable. What is important to note is that comparisons of the two vessels made for the same sea conditions are valid for that seaway.

Figure 18 illustrates the general superiority of the smaller 210-ft WMEC to the unstabilized 270-ft WMEC for both seaways. The effect of the larger roll that the 270-ft cutter experiences with its fins stabilization system inactive (approximately 1½ times as much roll as the 210-ft cutter) dominates these results. Substantial MII reduction should be expected with successful roll stabilization. Nevertheless, the large predicted MII numbers tend to correlate with the documented impact that ship motions had on actual crew performance as reported in the previous section (Figures 13 and 14). The two ships, both without stabilization, show close correlation at the pilothouse and Communications Center for the 9-second period example only. The 270-ft WMEC with fins off can be expected to induce more crew performance degradation in terms of manual tasks than the 210-ft WMEC.

[Note that the reduction in MII for the 11-second modal period, particularly noticeable for the 210-ft cutter, is due to the smaller amplitudes for all motions across all headings. Also, the use of RMS motion values rather than a higher statistic (e.g., 2xRMS or significant values) directly affects the magnitudes of MII expected in 2 hours.]

The results of the MSI predictions for the four ship locations presented in Figure 19 helps to substantiate earlier conclusions about the impact of work station placement made in SHIP PERFORMANCE - ANALYTICAL. The two areas known for high crew degradation on the BEAR show high MSI occurrence; that is, the pilothouse/CSC and the Communications Center. Moreover, these locations are worse for the 270-ft WMEC when compared to the 210-ft ship. In contrast, the crew's mess shows not only low MSI for the 270-ft cutter but generally lower MSI occurrence than the smaller cutter.

The MII and MSI results help to confirm the subjective impression of the 270-ft WMEC as a poorer riding ship than the 210-ft cutter. These human factors measurements directly relate to the rider's perceptions. Even though it has been shown that the 270-ft WMEC motions, in general, are less than the smaller cutter, the placement of critical work areas (including officers' staterooms) have compromised the advantages of the BEAR Class' longer ship length. In terms of working in these areas, the difficulty due to ship motions that has been observed is indeed a reality.

FIN PERFORMANCE

As part of the seakeeping trials conducted on board the USCGC BEAR, anti-roll fin stabilizer system performance was to be evaluated. This evaluation, however, became an extensive and involved process because of a number of deficiencies in the design and operation of the system. For that reason, a separate report has been prepared to document the fin system assessment (see Reference 8).

To summarize the findings of this report, the following problems were identified: intermittent excessive travel of the port fin; improper speed input into the controller; incorrect operation of the MANUAL versus AUTOMATIC GAIN modes by the crew; and, a defective roll angle sensor which degraded the control algorithm, particularly in quartering seas.

It was further discovered by subsequent data reduction that highly desirable alterations should be made to increase the size of the bilge keels and fins to obtain optimum roll damping. Such changes are considered crucial in order to overcome the excessive degradation in crew performance (i.e., fatigue and MII occurrence) caused by the large vertical accelerations at the ship's work areas.

In addition to fin enlargement, corrective actions are recommended to bring all BEAR-Class fin systems up to full capacity. These include step-by-step instructions for crew members in the check-out and operation procedures, and a reduction in the maximum fin angle limit from ±24 degrees to ±20 degrees.

CONCLUSIONS

Based on the data analysis presented, the following conclusions are reached:

FULL-SCALE TRIALS

1. Two limiting speed conditions were attained. Run 29 (7 to 8-foot, port beam seas with fins off) produced a 30-degree roll which the Commanding Officer felt was excessive and ordered a speed reduction from 18 to 15 knots. More importantly, during Run 36 (7 to 8-foot head seas with fins on) slamming and minor damage on the forecastle due to the shipping of water resulted in two speed reductions from 16 to 15 knots, and eventually to 12 knots. These sea conditions, equivalent to a low Sea State 5, are not considered unusual nor extreme.

2. Deck wetness is a major class problem for the 270-ft WMEC. However, the vast majority of wetness is the result of sea spray and not green water.

3. Design of the 270-ft class cutters has placed critical habitated areas, specifically the pilothouse, CSC, and the Communications Center, at ship locations of high vertical motion. In terms of human factors, the perception of a poor ride including the high incidence of seasickness is not unusual when the distance of the center of gravity is considered. Moreover, the placement and orientation of manned work stations within the CSC and Communications Center contributes significantly to the uncomfortable ride at these locations.

4. Department head assessments from the questionnaires indicate that excessive ship motions, causing mechanical/manual interference, is the primary cause of crew performance degradation; shipboard performance impairment due to all causes ranged from a low of 29 percent to a high of 61 percent.

5. From Reference 8, roll stabilization measurements from the BEAR trials do not provide an accurate description of the roll reduction which can be achieved on this class ship. Deficiencies in the system as installed, how it was operated during the trials, and, ultimately, its original design indicate that far better performance of the fin system can be attained with relatively minor, cost-effective alterations.

ANALYTICAL

6. Ship motion magnitudes for the 270-ft WMEC are less than, or comparable to, the smaller 210-ft WMEC for all investigated locations. The exception is roll. However, effective fin stabilization on the 270-ft vessel should reduce the roll amplitudes to at or below those of the 210-ft WMEC.

7. Ship location of primary work stations aboard the 270-ft WMEC class has contributed to the ride degradation in these areas. Specifically, the forward placement of critical spaces such as the pilothouse, CSC, and Communications Center has created a motion environment in these areas comparable to the 210-ft WMEC. This, it is believed, is responsible for the perception that the 270-ft vessel is a poor seakeeper.

8. Comparison of four work areas aboard an unstabilized 270-ft WMEC versus the same work stations on the 210-ft WMEC indicates ship motions will be a significant impairment on the larger vessel in terms of biomechanical (manual) tasks. In terms of motion sickness incidence, the 270-ft ship exhibits comparable or less occurrence than the 210-ft ship.

RECOMMENDATIONS

Based on the above conclusions, the following recommendations are proposed:

1. It is recommended that a four day side-by-side sea trial between the 270-ft Medium Endurance Class cutter and the 210-ft Medium Endurance Class cutter be conducted.

2. It is recommended that a relatively minor above-water hull shape modification be considered and implemented for the 270-ft WMEC in order to alter spray patterns and reduce the resulting deck wetness caused by spray and white water. Specifically, the addition of a deep knuckle with added flare is suggested as described in Reference 9. This bow shape should be most effective particularly if a solid bulwark can not be added due to forward gun interference considerations. Since construction of the knuckle entails dropping straight down from the existing main deck and then fairing into the hull with increased flare, no interior spaces need to be disturbed or altered. Moreover, the cost of this modification is relatively low and the added weight forward, due only to the steel shell plating and required strengtheners, will be kept to a minimum. Two important points concerning this type of hull modification: (a) the additional flare will not significantly reduce the occurrence of green water wetness; and, (b) the addition of a knuckle will produce increased structural forces and loads which require tying into the hull girder and, thus, special consideration during modification design and construction.[9]

3. From Reference 8, it is recommended that

   (a) detailed operator guidance be provided to each ship of the BEAR-class to allow routine and complete fin system check-outs in order to determine proper functioning;

   (b) increasing fin size, and also bilge keel size, be considered to provide additional roll stabilization capability and thus reduce crew performance degradation; and,

   (c) the maximum fin limit be decreased from ±24 degrees to ±20 degrees to reduce the occurrence and severity of cavitation.

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Figure 1 - Course Pattern Used for Seakeeping Trials Aboard USCGC BEAR

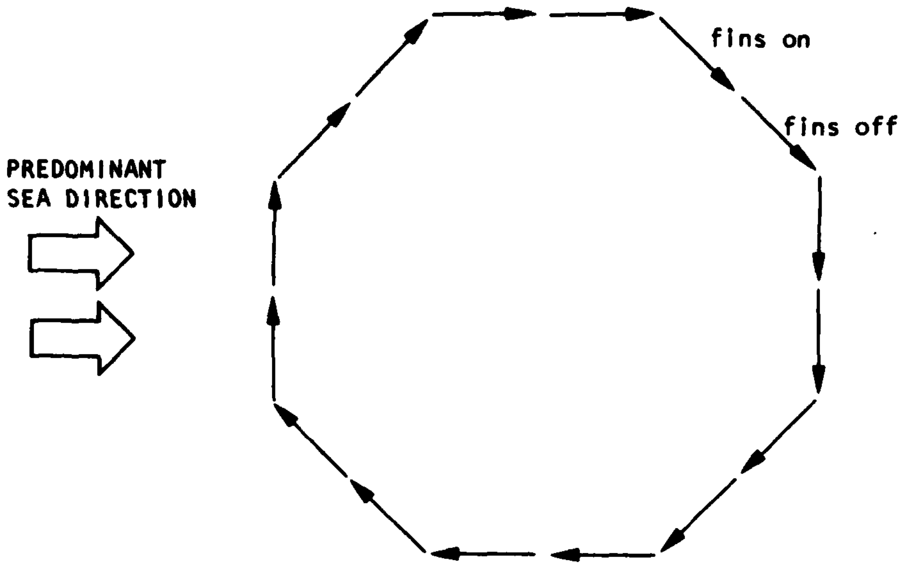


Figure 1a - Octagonal Course Pattern Used for First Sea Trial, March 1984

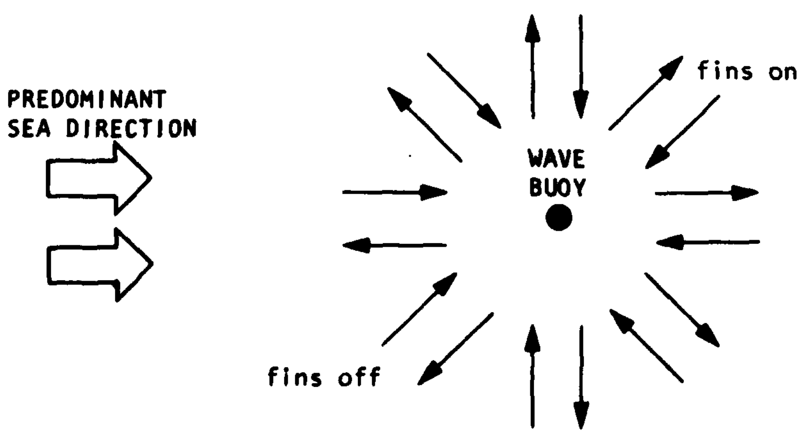


Figure 1b - Crisscross Course Pattern Used for Second Sea Trial, April 1984

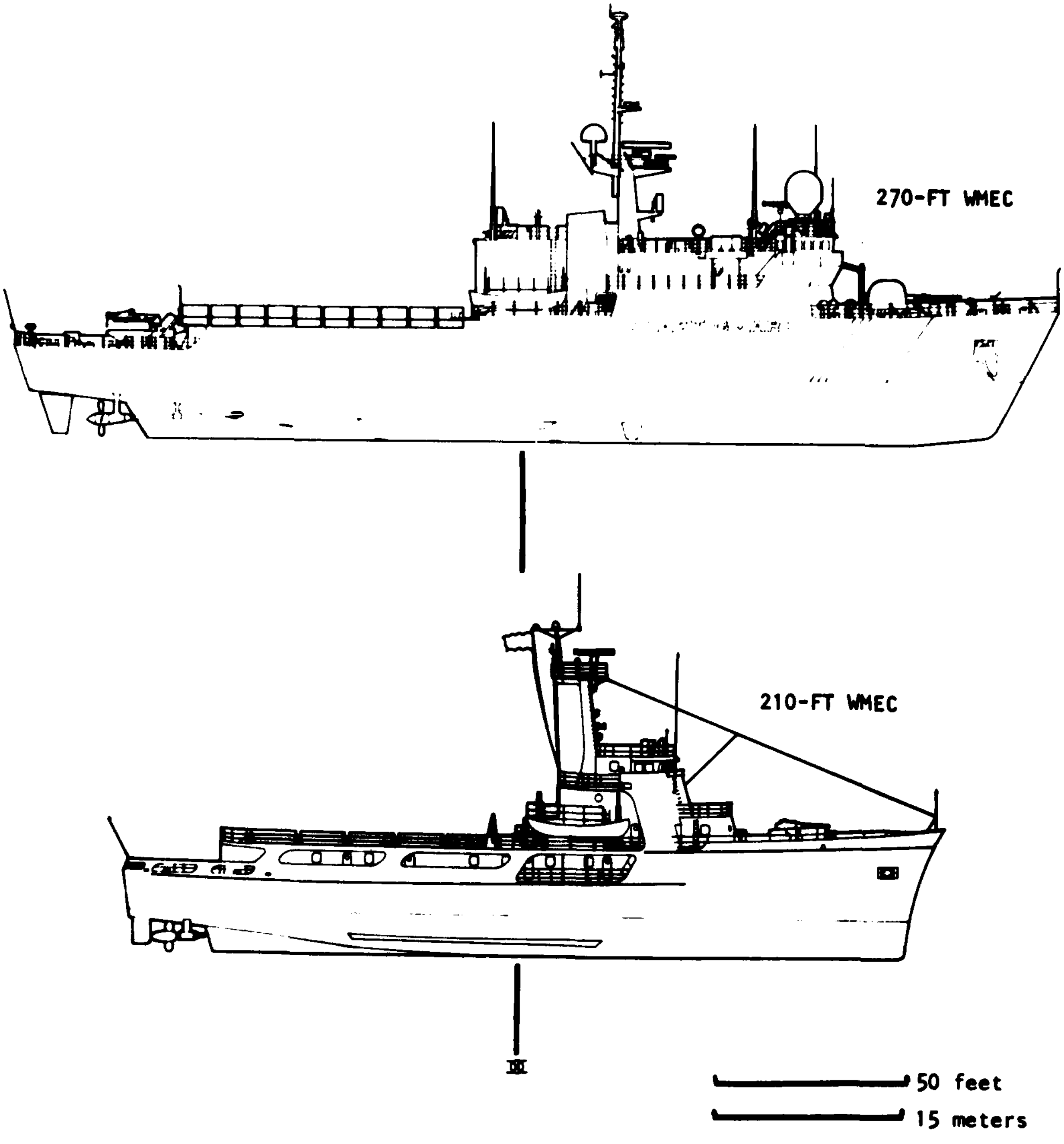


Figure 2 - Outboard Profiles of the 270-ft WMEC and the 210-ft WMEC

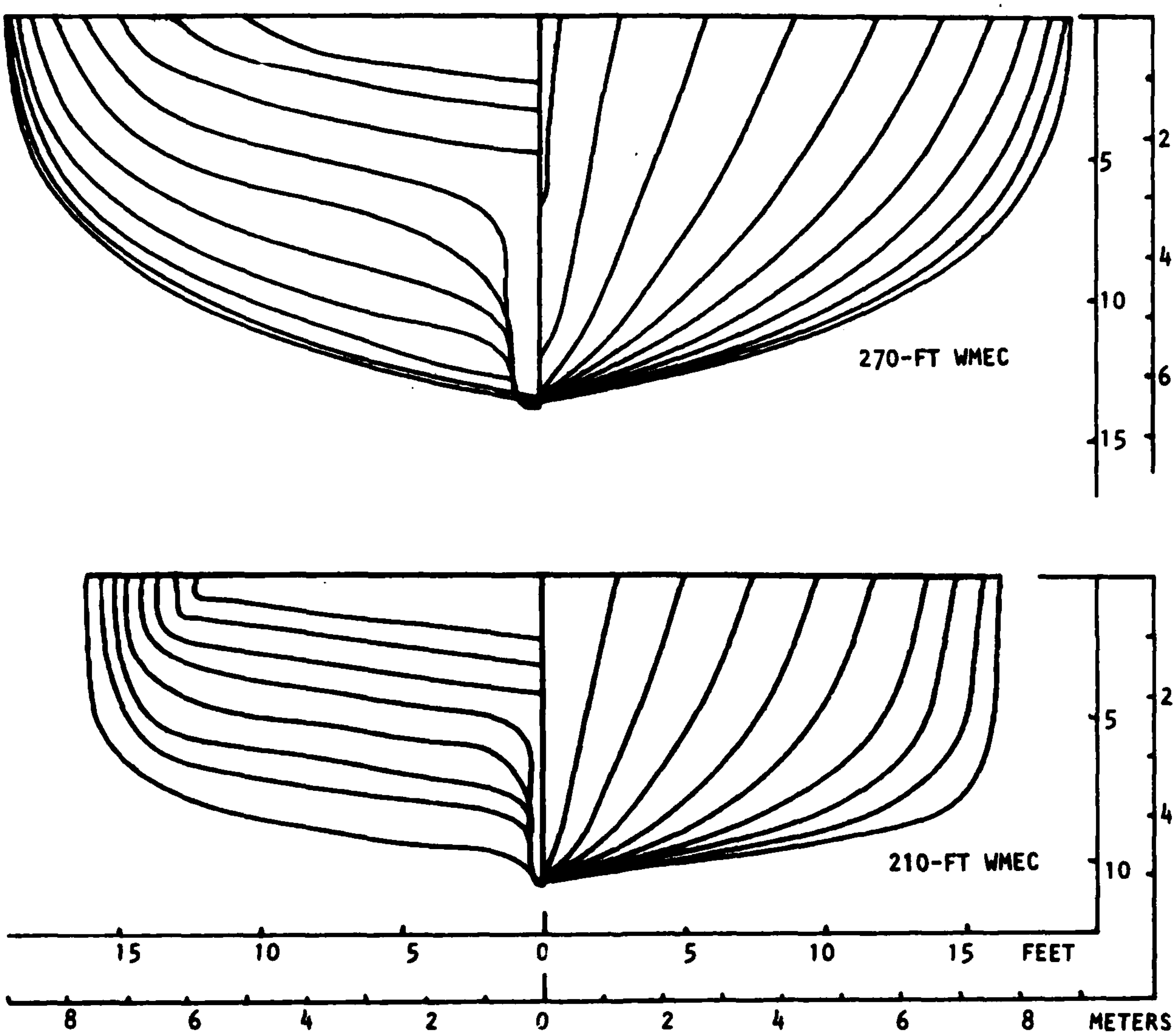
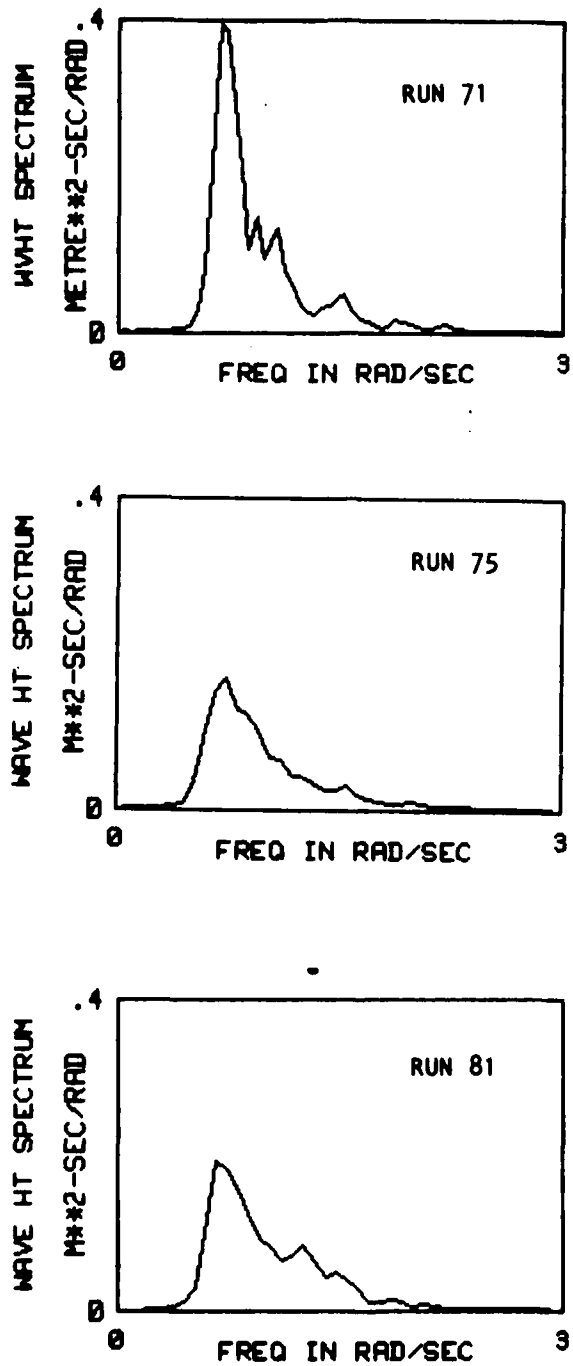


Figure 3 - Computed Hull Configurations for the 270-ft WMEC and 210-ft WMEC



T_o = 9.1 sec
$(\tilde{\zeta})_{1/3}$ = 6.2 feet
= 1.89 meters

T_o = 8.5 sec
$(\tilde{\zeta})_{1/3}$ = 4.6 feet
= 1.40 meters

T_o = 9.5 sec
$(\tilde{\zeta})_{1/3}$ = 4.9 feet
= 1.49 meters

Figure 4 - Corrected Wave Spectra as Measured During USCGC BEAR Sea Trial, April 1984

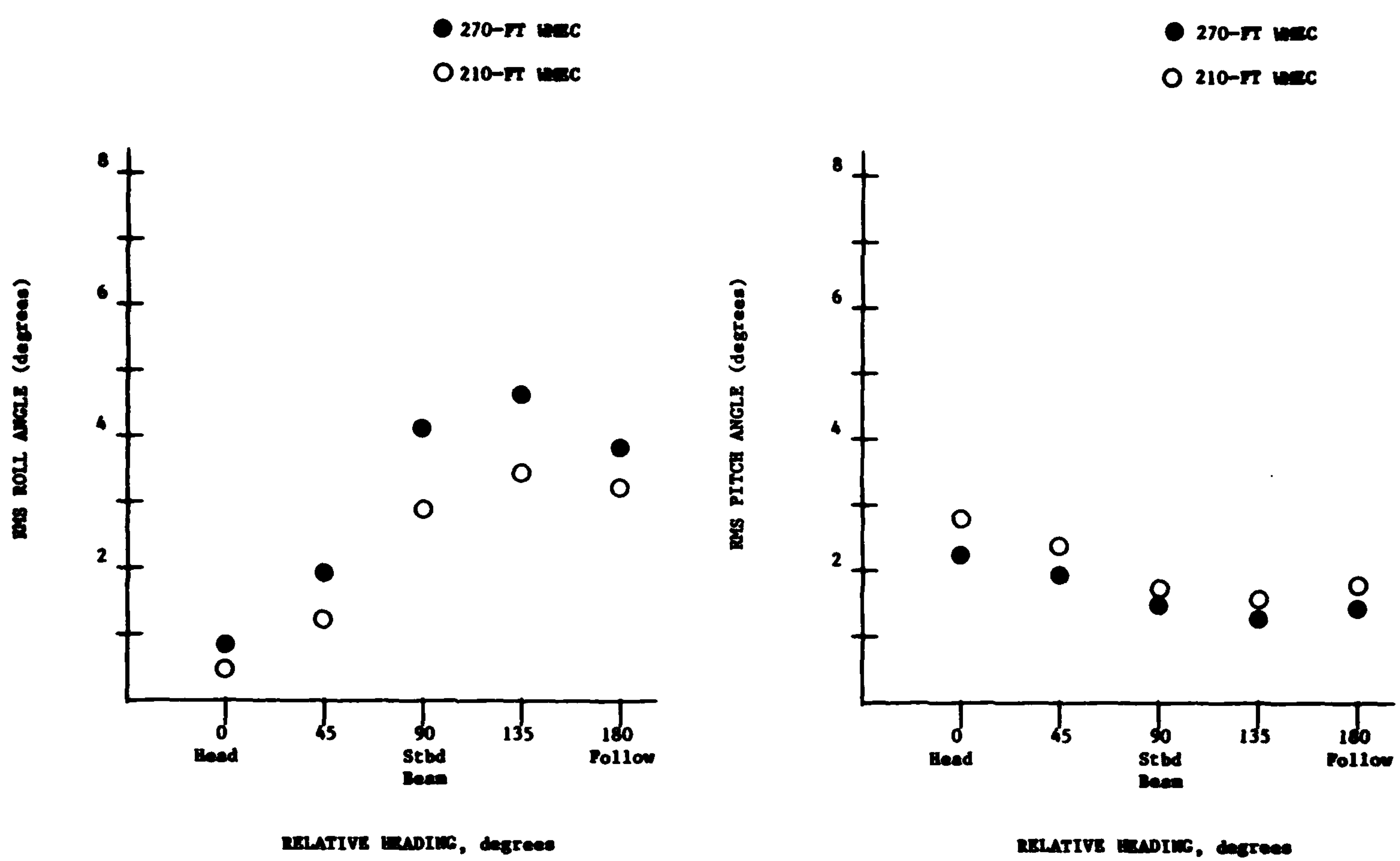


Figure 5 - Comparison of Predicted RMS Roll and Pitch Angles for the 270-ft and 210-ft WMEC's at 15 knots for a High Sea State 5

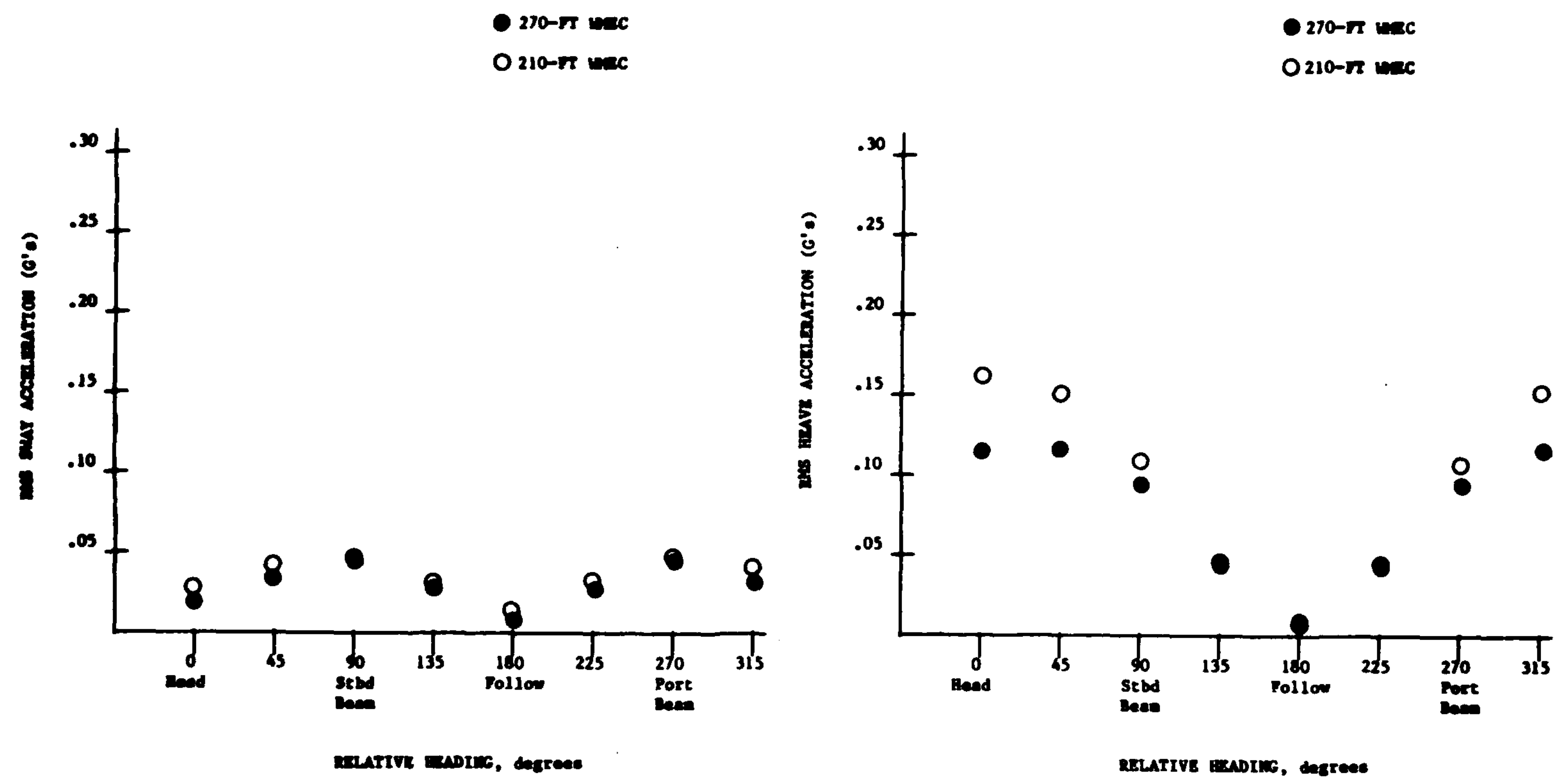


Figure 6 - Comparison of Predicted RMS Sway and Heave Accelerations at the Center of Gravity for the 270-ft and 210-ft WMEC's at 15 knots for a High Sea State 5

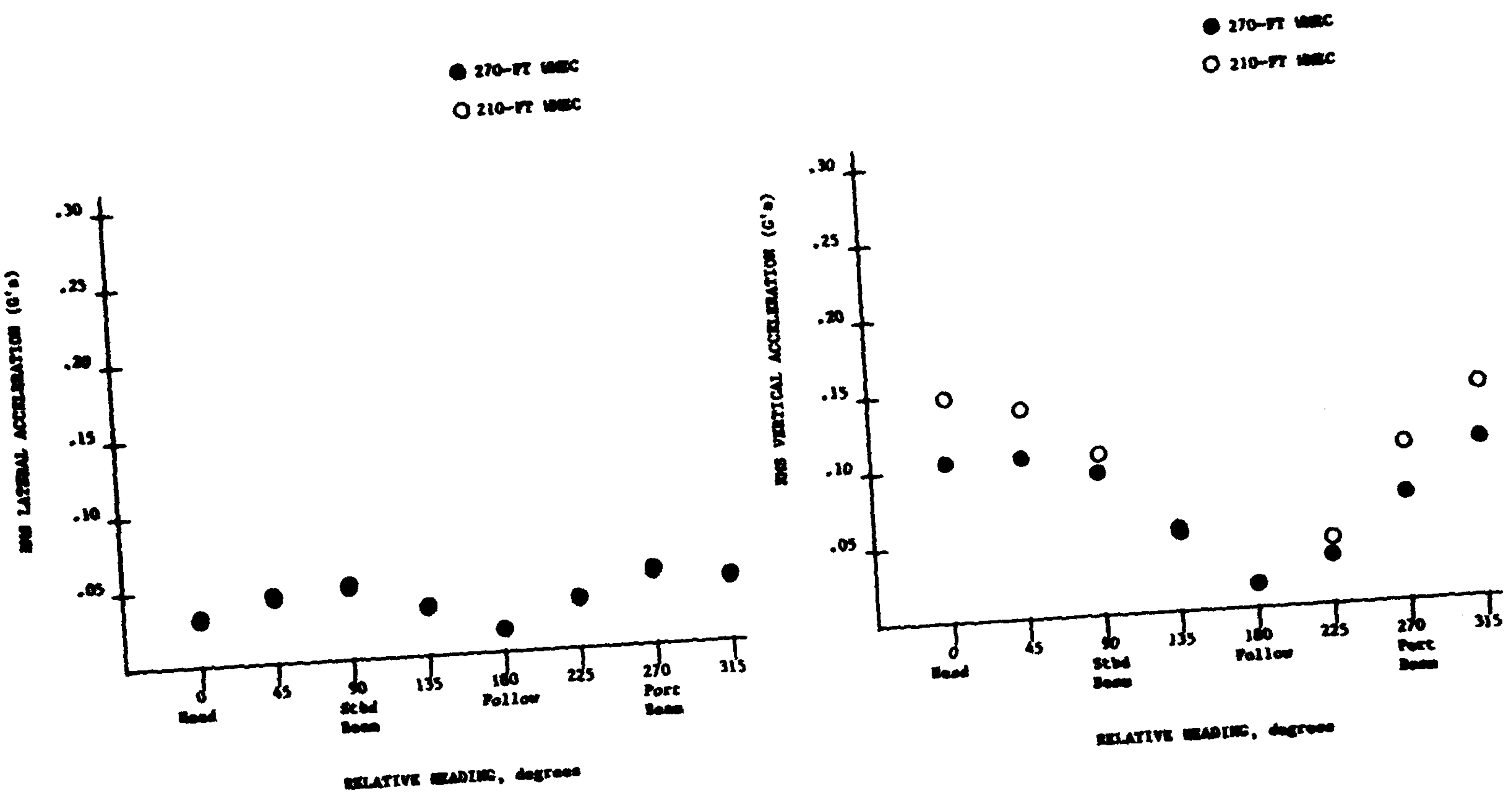


Figure 7 - Comparison of Predicted RMS Lateral and Vertical Accelerations at the Crew's Mess for the 270-ft and 210-ft WMEC's at 15 knots for a High Sea State 5

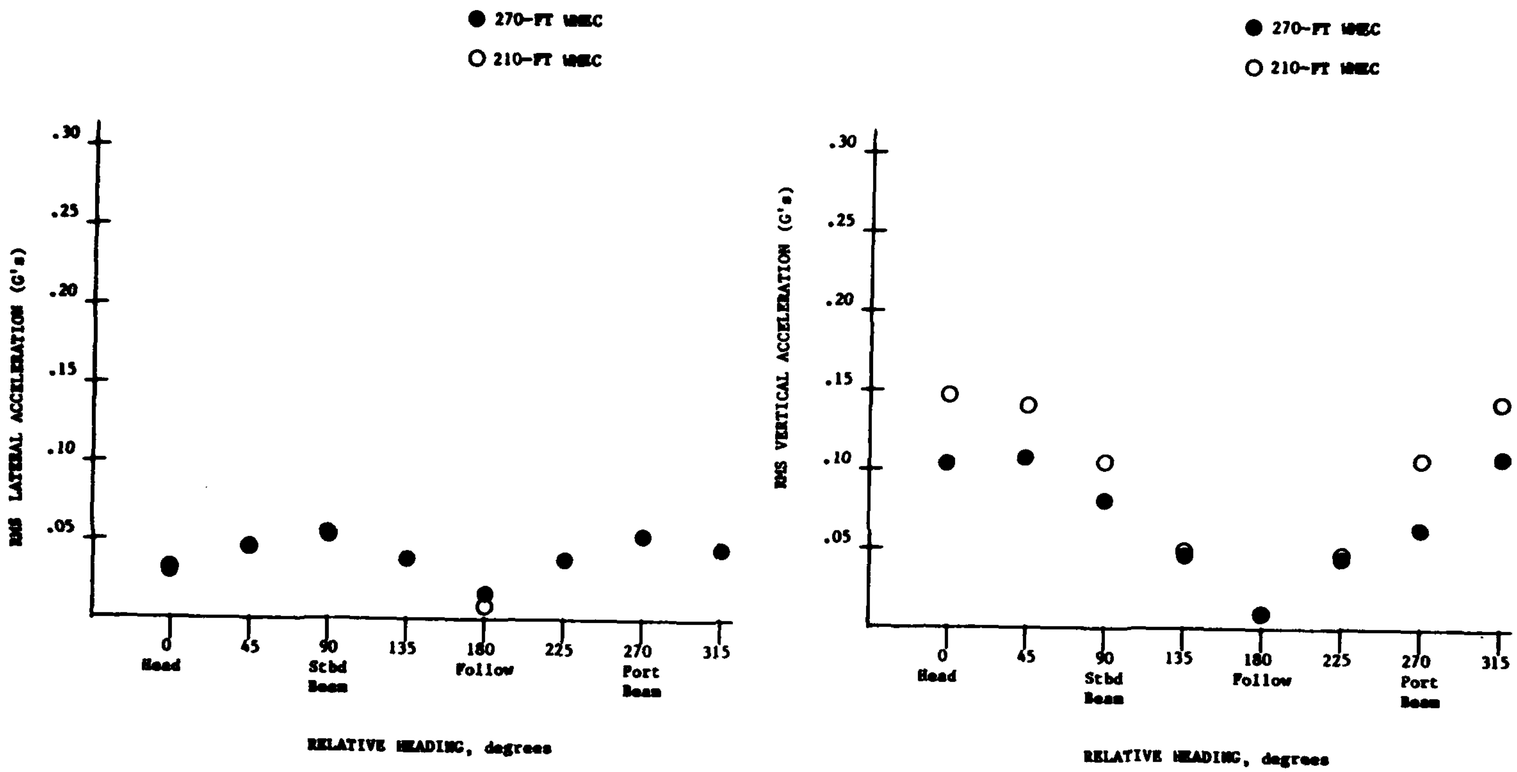


Figure 8 - Comparison of Predicted RMS Lateral and Vertical Accelerations at the Helicopter Flight Deck for the 270-ft and 210-ft WMEC's at 15 knots for a High Sea State 5

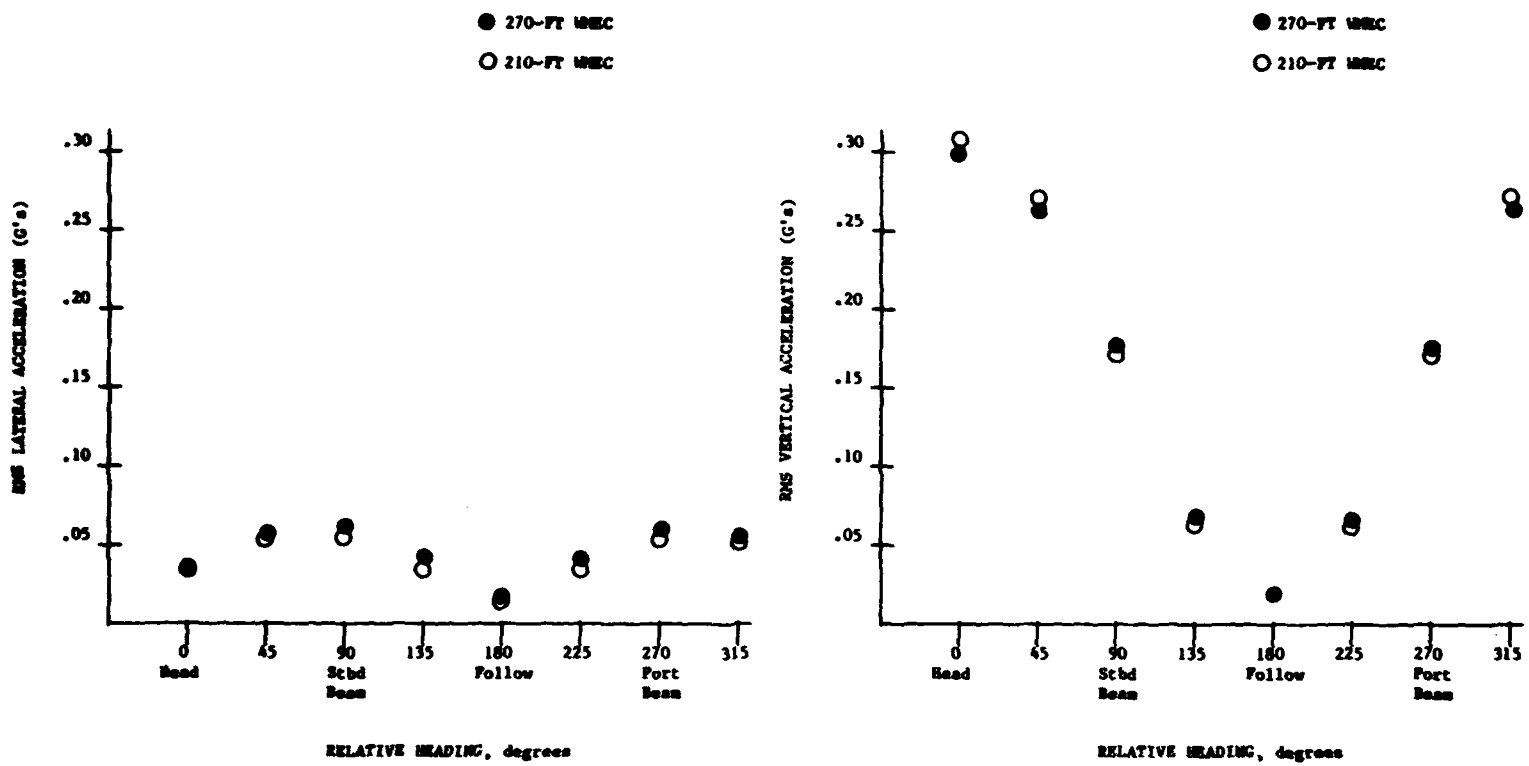


Figure 9 - Comparison of Predicted RMS Lateral and Vertical Accelerations at the Gun Mount for the 270-ft and 210-ft WMEC's at 15 knots for a High Sea State 5

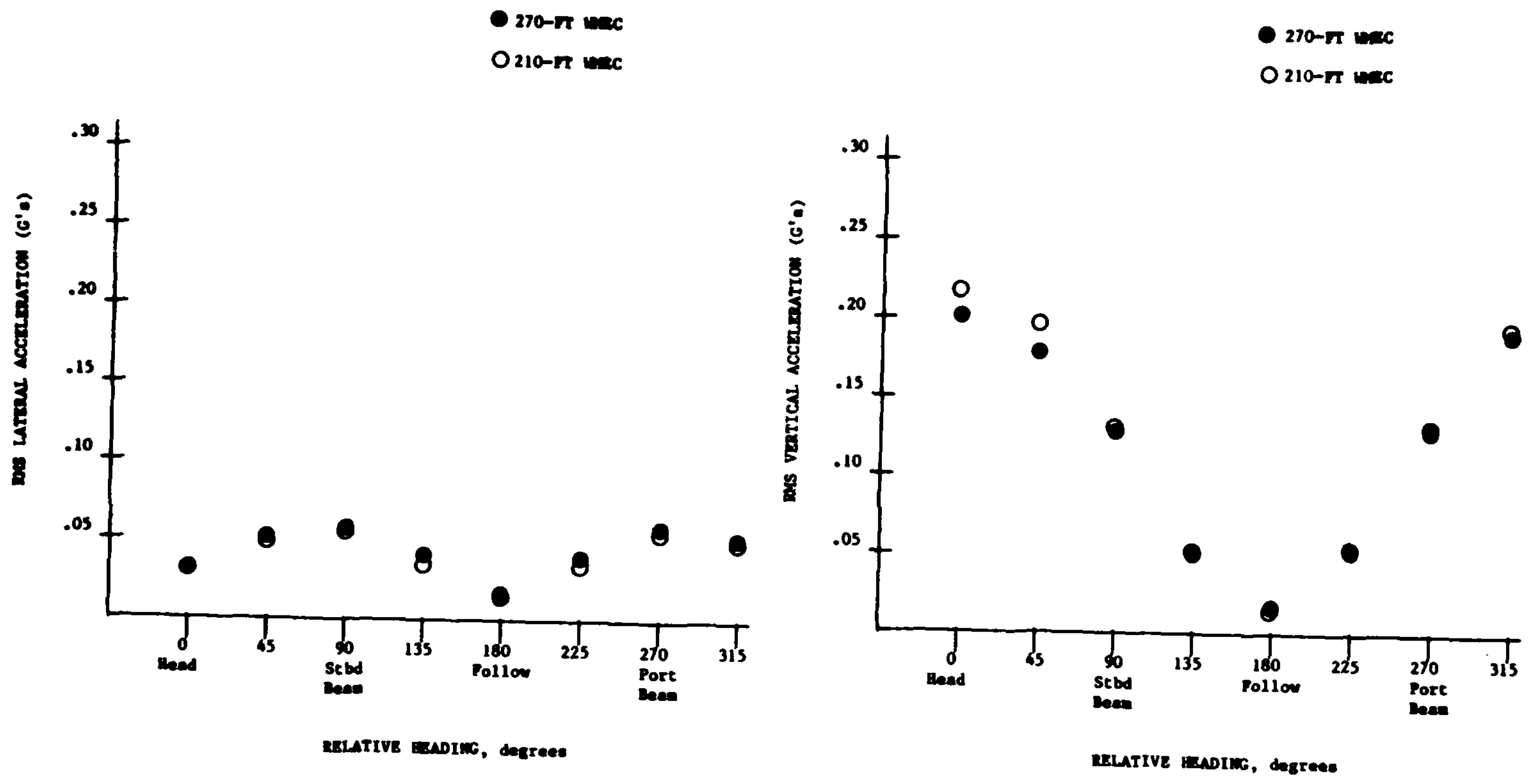


Figure 10 - Comparison of Predicted RMS Lateral and Vertical Accelerations at the Pilothouse for the 270-ft and 210-ft WMEC's at 15 knots for a High Sea State 5

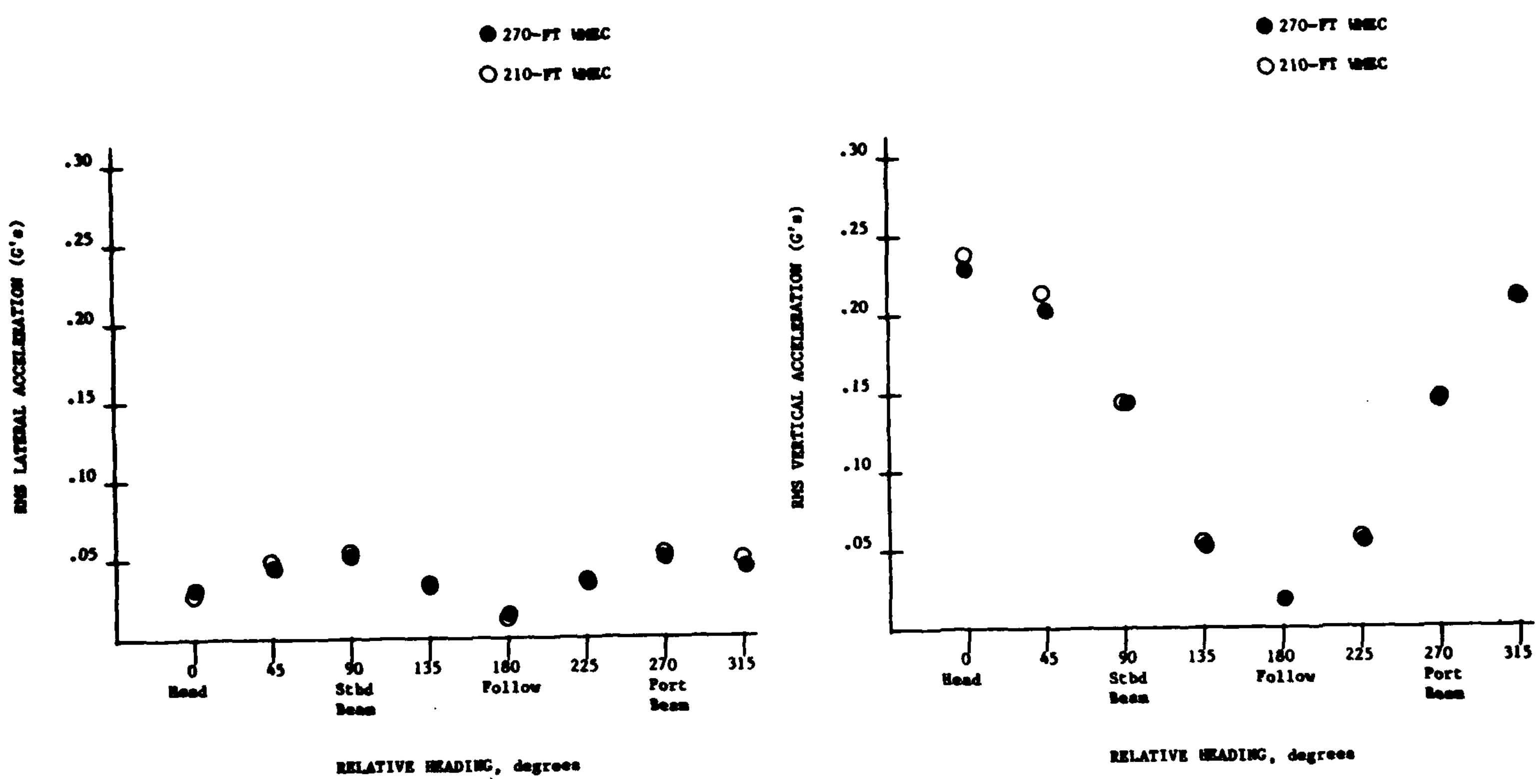


Figure 11 - Comparison of Predicted RMS Lateral and Vertical Accelerations at the Communications Center for the 270-ft and 210-ft WMEC's at 15 knots for a High Sea State 5

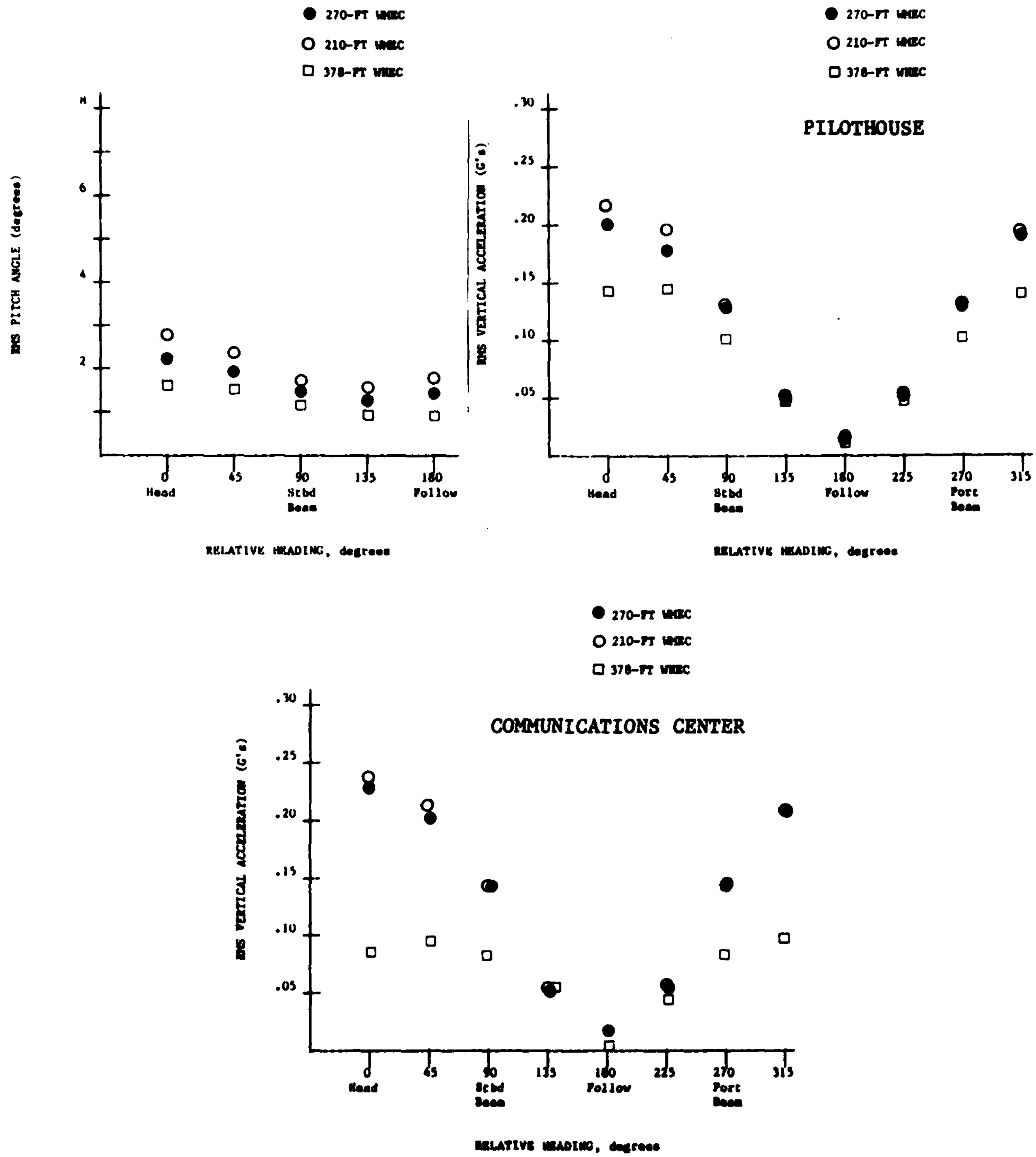


Figure 12 - Comparison of Predicted RMS Pitch Angle and Vertical Accelerations at the Pilothouse and Communications Center for the 270-ft and 210-ft WMEC's, and the 378-ft WHEC at 15 knots for a High Sea State 5

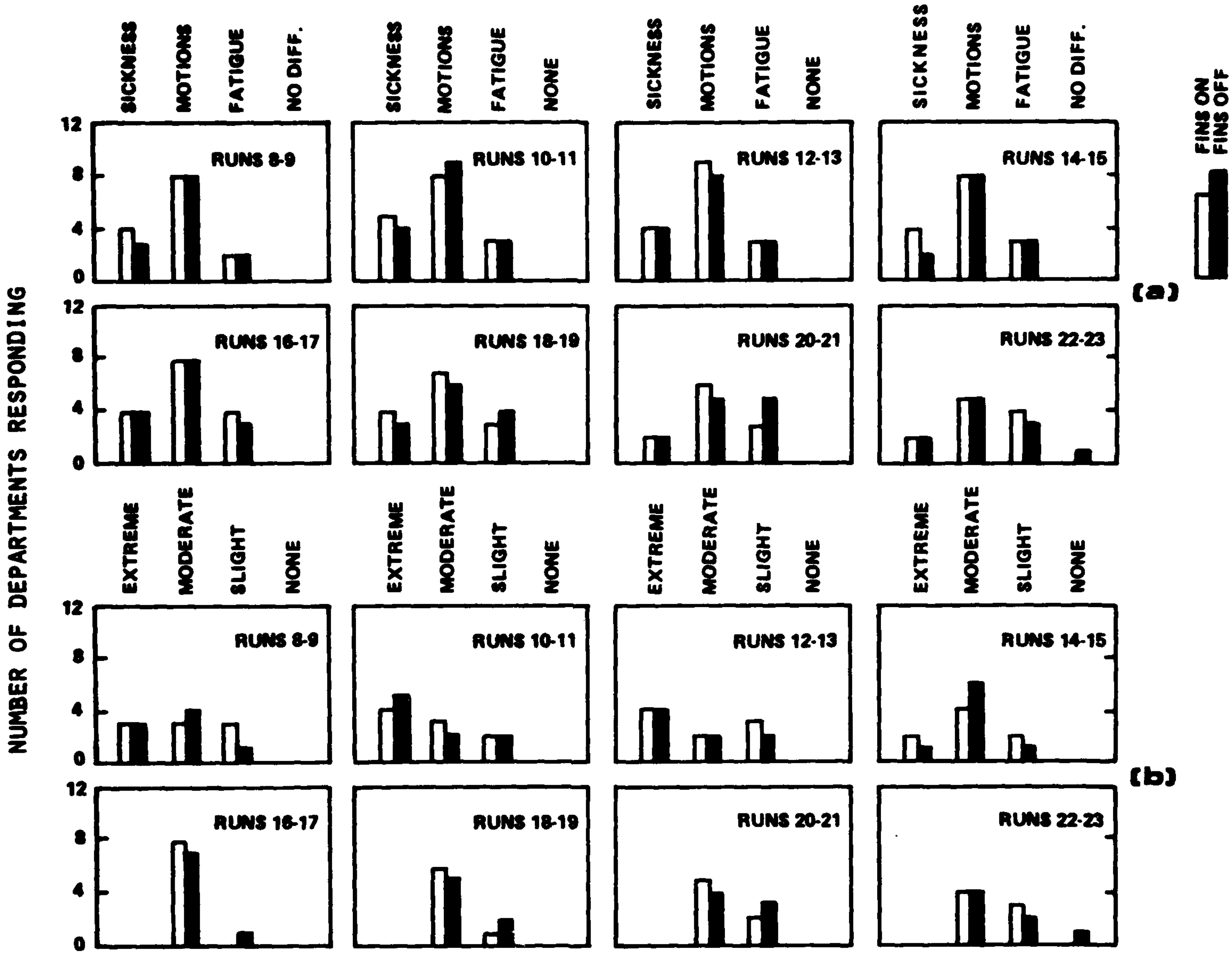


Figure 13 - Summary of Department Heads' Assessments: Causes of Crew Performance Degradation (a) and Degree of Impairment (b) during Sea Trial, March 6, 1984

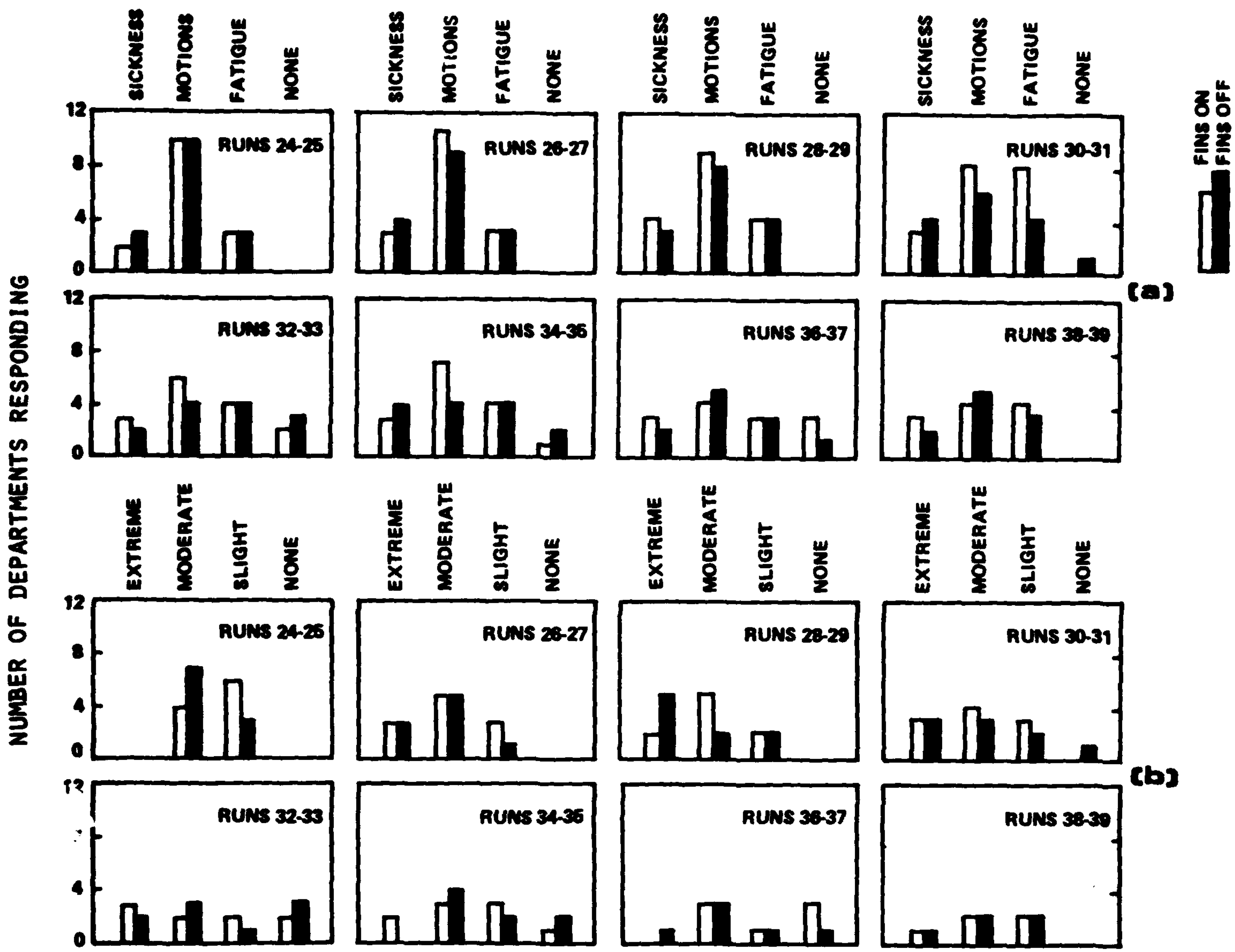


Figure 14 - Summary of Department Heads' Assessments: Causes of Crew Performance Degradation (a) and Degree of Impairment (b) During Sea Trial, March 7, 1984

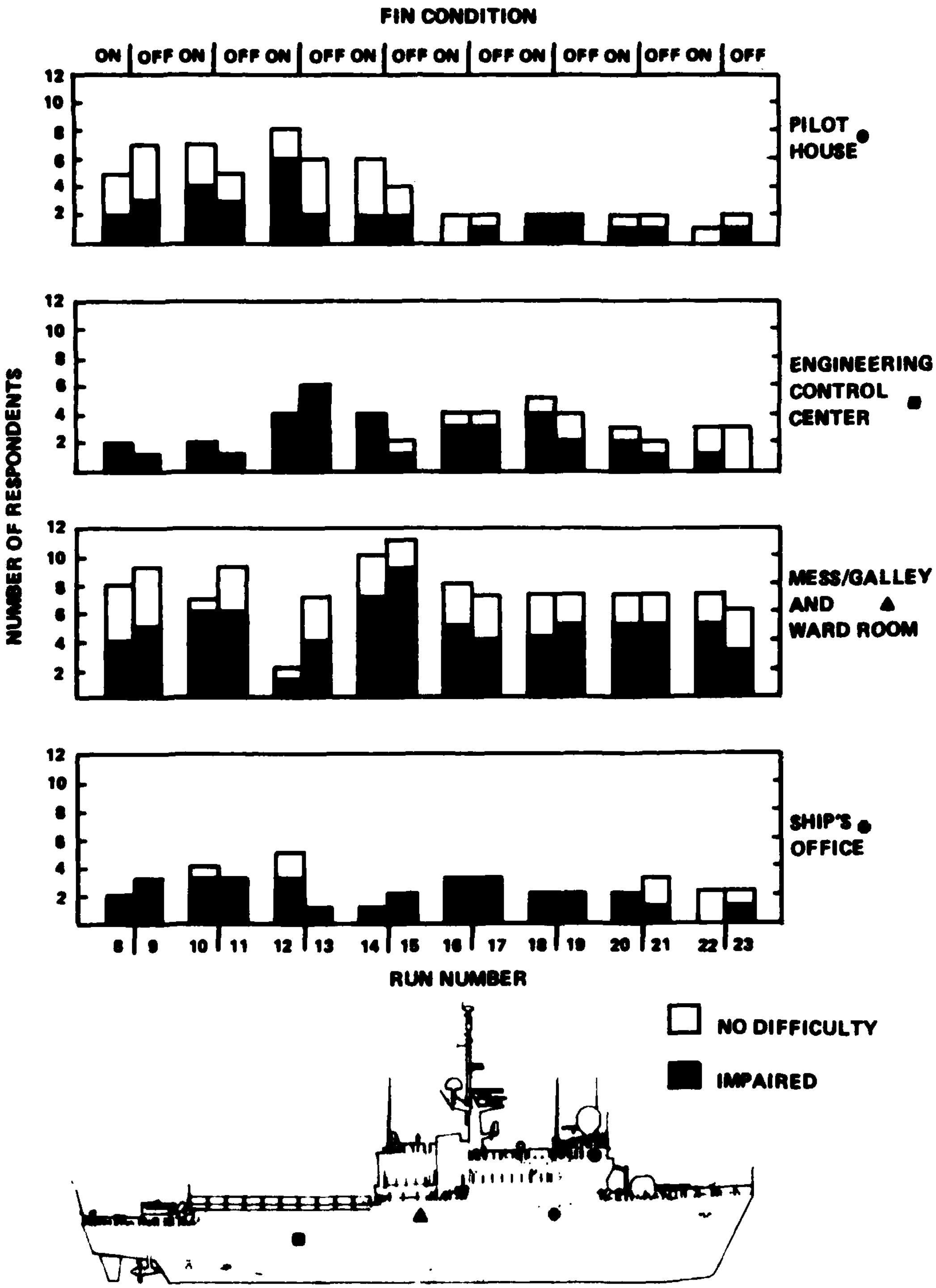


Figure 15 - Individual Assessments by Crew Respondents for Four Ship Locations During Sea Trial, March 6, 1984

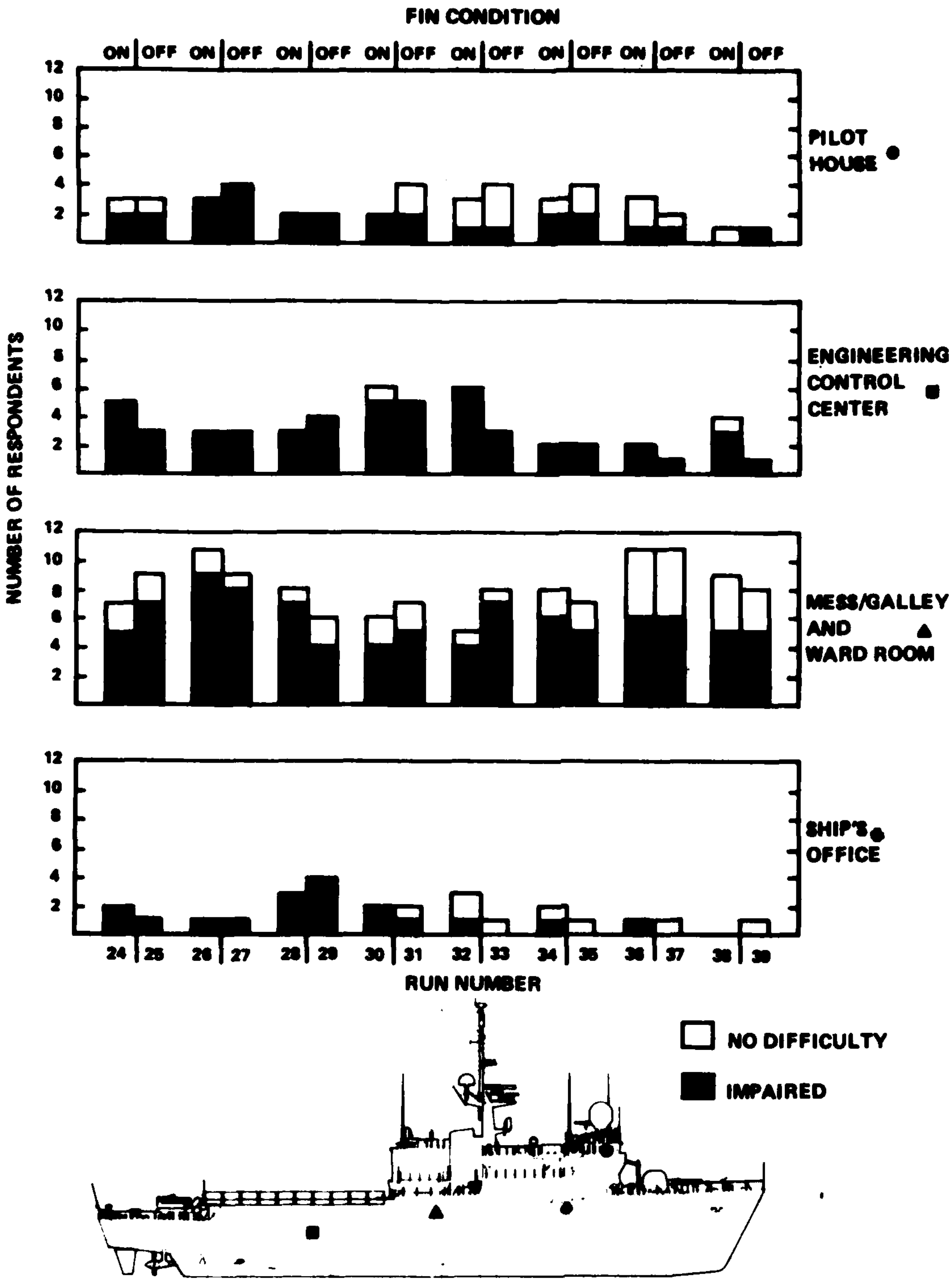


Figure 16 - Individual Assessments by Crew Respondents for Four Ship Locations During Sea Trial, March 7, 1984

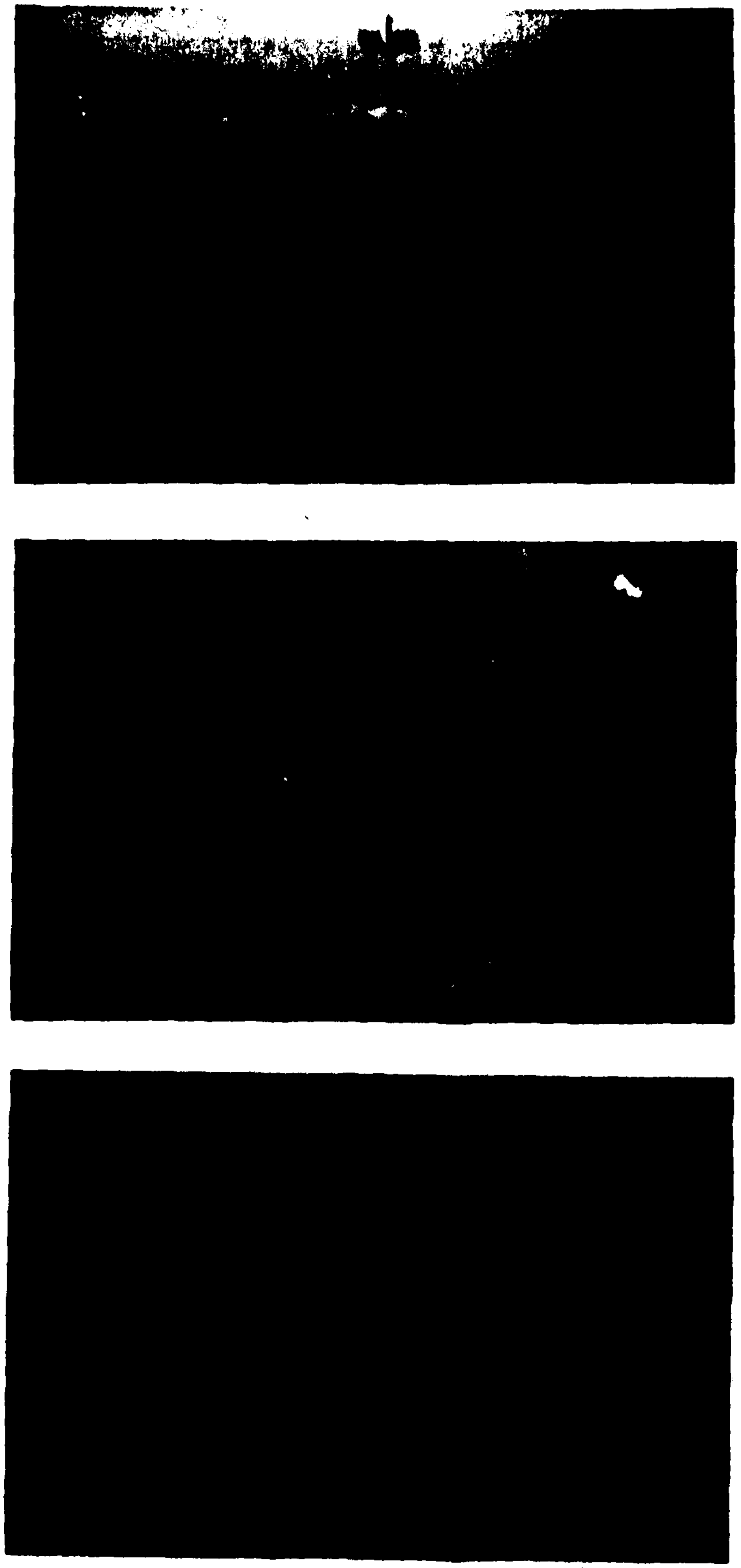


Figure 17 - Photographic Series Illustrating Deck Wetness in the Form of White Water and Spray Aboard a 210-ft WMEC

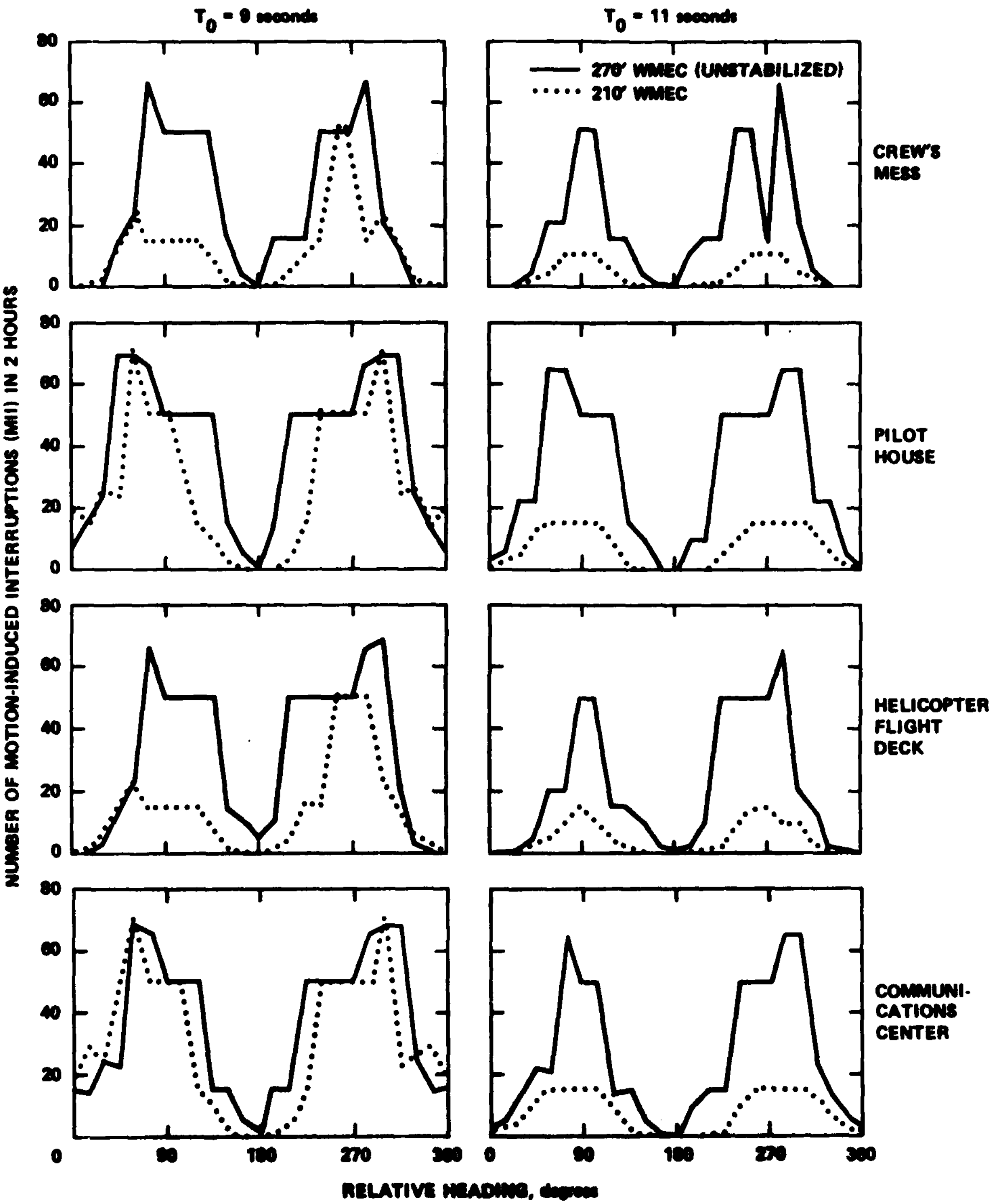


Figure 18 - Comparison of Predicted, Motion-Induced Interruptions Between the Unstabilized 270-ft WMEC and the 210-ft WMEC at 15 knots at Four Ship Locations for Two Seaways

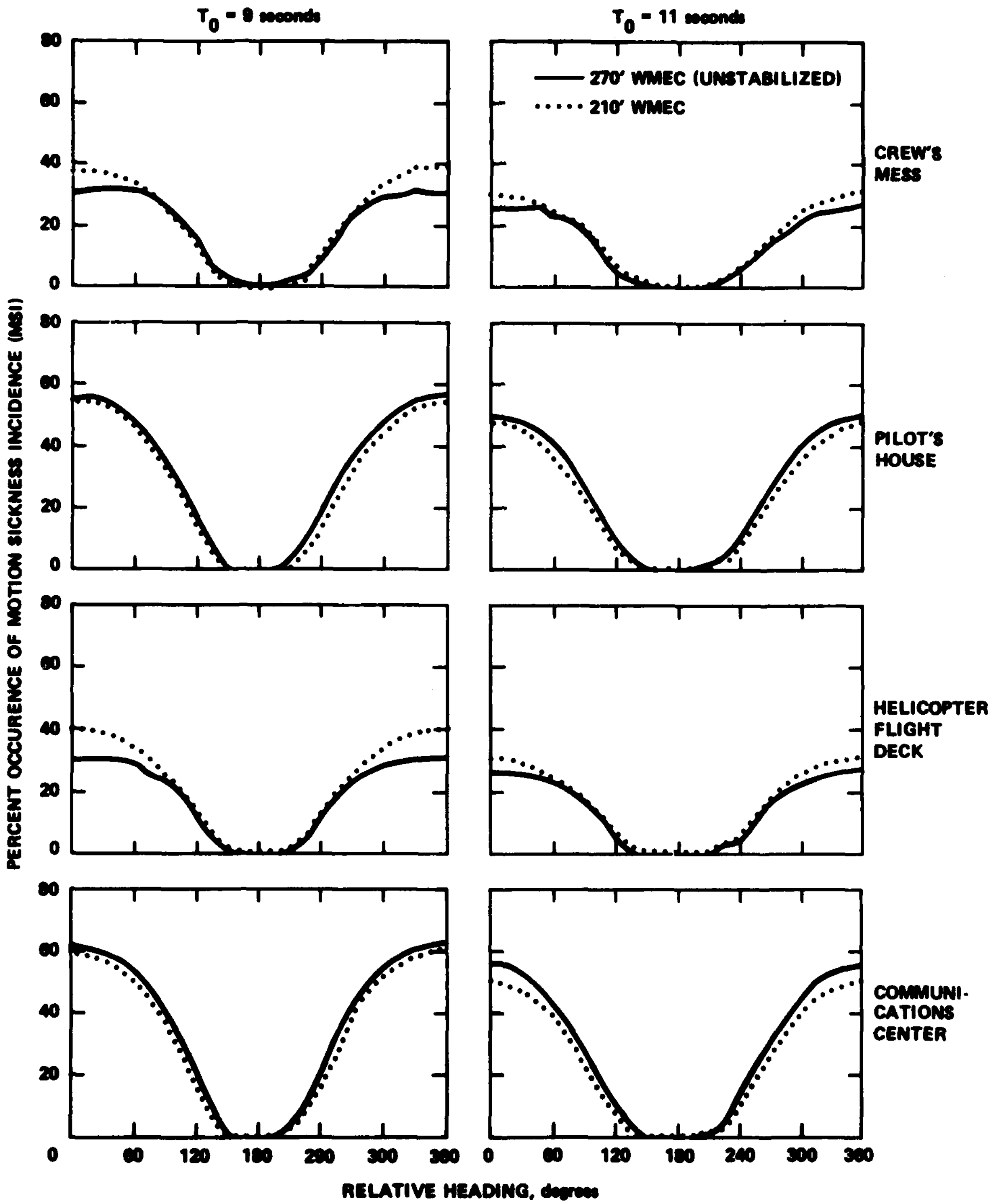


Figure 19 - Comparison of Predicted Motion Sickness Incidence Between the Unstabilized 270-ft WMEC and the 210-ft WMEC at 15 knots at Four Ship Locations for Two Seaways

TABLE 1 - MOTION SENSOR LOCATIONS FOR WMEC 901
SEAKEEPING TRIAL, MARCH 1984

POINT†	LOCATION	X-DISTANCE FROM FP (feet/meters)	Y-DISTANCE FROM CL* (feet/meters)	Z-DISTANCE FROM BL (feet/meters)
0	Engine Room (Center of gravity)	119.5/36.4	-4.6/-1.4	11.0/ 3.3
1	Crew's Mess	146.0/44.5	-17.8/-5.4	28.3/ 8.6
2	Pilothouse/CSC	70.0/21.3	4.2/ 1.3	48.3/14.7
3	Helo Flight Deck	177.0/53.9	-3.4/-1.0	29.7/ 9.0
4	Communications Center	54.0/16.5	4.9/ 1.5	14.3/ 4.4
5	Gun Mount	15.5/ 4.7	0.0/ 0.0	27.9/ 8.5

† Points 1-5 represent locations for which analytical computations were also performed.

* Positive to port of the centerline.

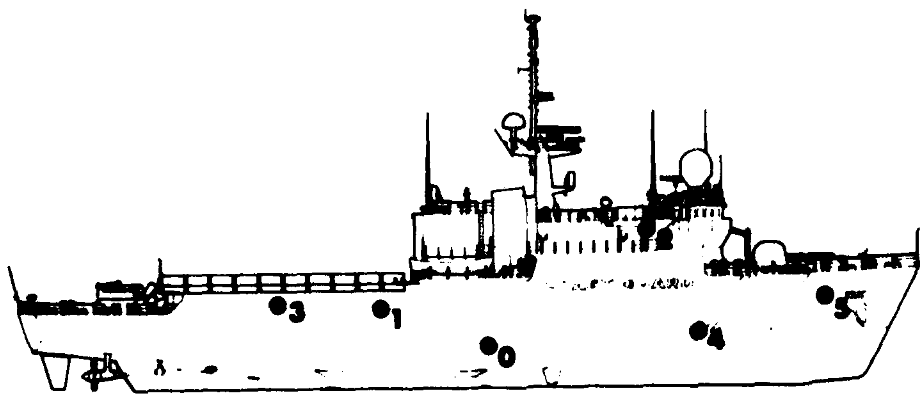


TABLE 2 - COMPUTED SHIP PARTICULARS

	270-ft WMEC (feet/meters)	210-ft WMEC (feet/meters)
Length Between Perpendiculars, Lpp	255.0 / 77.7	200.0 / 61.0
Beam at Midships, B	38.0 / 11.6	33.0 / 10.1
Mean Draft, T	13.8 / 4.2	10.8 / 3.3
Displacement, Δ, Long tons	1790	1009
Vertical Center of Gravity, KG	16.9 / 5.2	15.0 / 4.6
Metacentric Height, GM	3.1 / 0.9	2.0 / 0.6
Longitudinal Center of Gravity, LCG*	130.9 / 39.9	103.2 / 31.5
Roll Gyradius	15.6 / 4.8	12.5 / 3.8
Pitch Gyradius	61.2 / 18.7	50.0 / 15.2
Yaw Gyradius (.25B)	63.8 / 19.5	50.0 / 15.2
Block Coefficient	.47	.49
Section Coefficient	.77	.84
Prismatic Coefficient	.61	.59
Bilge Keel Length	52.0 / 15.9	65.0 / 19.8
Bilge Keel Span	2.0 / 0.6	1.9 / 0.6
Rudder Mean Chord	6.0 / 1.8	5.2 / 1.6
Rudder Mean Span	10.0 / 3.1	6.7 / 2.0
Fin Mean Chord	4.9 / 1.5	----
Fin Mean Span	5.1 / 1.6	----

* Referenced to F.P.

TABLE 3 - SHIP POINT LOCATIONS FOR 210-FT WMEC ANALYTICAL PREDICTIONS

POINT	LOCATION	X-DISTANCE FROM FP (feet/meters)	Y-DISTANCE FROM CL* (feet/meters)	Z-DISTANCE FROM BL (feet/meters)
1	Crew's Mess	132.0/40.2	-16.2/4.9	22.8/ 6.9
2	Pilothouse	70.8/21.6	4.2/1.3	47.5/14.5
3	Helo Flight Deck	137.2/41.8	-3.4/1.0	28.4/ 8.6
4	Communications Center	61.0/18.6	4.9/ 1.5	40.0/12.2
5	Gun Mount	30.0/ 9.1	0.0/ 0.0	28.9/ 8.8

* Positive to port of the centerline.

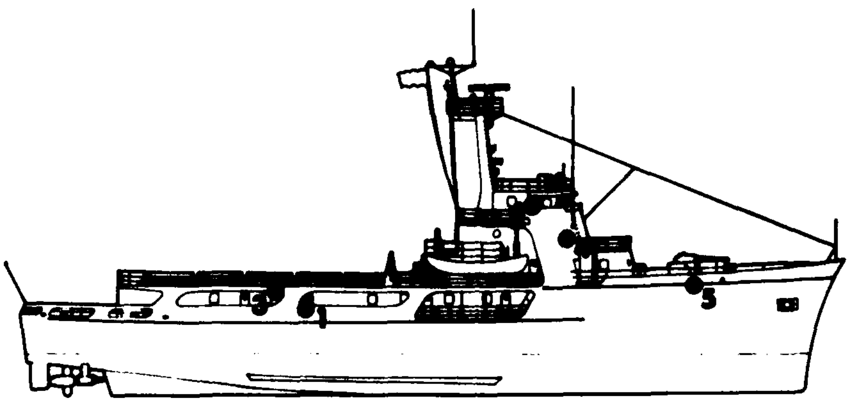


TABLE 4 - SUMMARY OF MEASURED SHIP MOTIONS DURING WMEC 901 SEA TRIALS, MARCH 6, 1984

RUN NUMBER				8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
FIN CONDITION				ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF
RELATIVE HEADING				STBD QTR	STBD QTR	FOLLOWING	FOLLOWING	PORT QTR	PORT QTR	PORT BEAM	PORT BEAM	PORT BOW	PORT BOW	HEAD	HEAD	STBD BOW	STBD BOW	STBD BEAM	STBD BEAM
SHIP SPEED (kts)				16	16	19	19	16-19	19	19	17	17	17	16	17	19	18	18	18
OBSERVED WAVE HEIGHT (ft)				14	14	14	14	13	8	8	7	7	6	6	6	6	6	6	6
ROLL (degrees)			RMS	7.56	8.30	7.07	-	5.92	5.54	6.30	6.41	1.24	3.54	1.55	2.65	1.41	2.13	1.40	2.30
			MAX	26.7	31.5	20.9	-	21.2	20.7	22.9	20.1	5.77	11.8	-	7.30	4.80	9.57	4.04	9.76
PITCH (degrees)			RMS	1.65	1.96	2.30	-	2.04	1.78	1.17	1.14	.93	.70	1.08	1.25	1.57	1.31	.95	1.01
			MAX	7.58	7.47	8.25	-	7.35	6.04	5.47	5.20	4.93	3.70	-	5.73	6.51	5.65	5.70	5.68
YAW (degrees)			RMS	15.3	3.90	9.94	-	15.3	16.5	5.00	2.95	-	1.20	2.00	.027	14.3	1.76	7.94	2.55
			MAX	30.9	22.4	30.9	-	30.9	30.9	30.9	10.7	-	4.32	-	37.6	30.9	5.63	30.9	7.30
ACCELERATIONS (G's)	CREW'S MESS	TRANSVERSE	RMS	[illegible]	[illegible]	[illegible]	-	110	[illegible]	127	125	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.087	[illegible]	[illegible]
			MAX	[illegible]	[illegible]	528	-	410	[illegible]	414	394	295	[illegible]	-	[illegible]	125	[illegible]	.122	[illegible]
		NORMAL	RMS	[illegible]	[illegible]	573	-	.0627	.0422	.0642	[illegible]	.0011	.076	[illegible]	[illegible]	[illegible]	.075	[illegible]	.072
			MAX	272	[illegible]	[illegible]	-	216	[illegible]	210	182	295	201	-	[illegible]	[illegible]	[illegible]	204	[illegible]
	PILOT HOUSE CSC	TRANSVERSE	RMS	138	241	254	-	140	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.075	[illegible]	[illegible]	.091
			MAX	732	[illegible]	[illegible]	-	626	-	-	-	-	-	-	-	-	-	-	-
		NORMAL	RMS	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	.0613	[illegible]	[illegible]	[illegible]	146	128	131	[illegible]	[illegible]	[illegible]
			MAX	387	381	195	-	233	138	190	[illegible]	376	[illegible]	-	481	[illegible]	[illegible]	381	[illegible]
	HELO FLIGHT DECK	TRANSVERSE	RMS	[illegible]	171	161	-	127	115	136	135	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	[illegible]
			MAX	591	627	[illegible]	-	428	441	[illegible]	446	385	391	-	-	[illegible]	[illegible]	[illegible]	[illegible]
		NORMAL	RMS	.0670	.0718	[illegible]	-	[illegible]	.0801	.0472	.0461	.0716	.0823	-	-	.0719	[illegible]	[illegible]	[illegible]
			MAX	246	282	224	-	194	172	215	[illegible]	282	210	-	-	[illegible]	[illegible]	[illegible]	234
	COMMUNICATIONS CENTER	TRANSVERSE	RMS	129	141	132	-	[illegible]	[illegible]	165	165	.0470	.0700	-	-	[illegible]	[illegible]	[illegible]	[illegible]
			MAX	465	575	528	-	392	414	365	332	165	283	-	-	122	[illegible]	127	[illegible]
		NORMAL	RMS	[illegible]	[illegible]	[illegible]	-	.0624	.0077	[illegible]	.0677	107	[illegible]	-	-	140	121	[illegible]	[illegible]
			MAX	386	384	287	-	212	142	281	[illegible]	383	317	-	-	[illegible]	471	[illegible]	[illegible]
	GUN MOUNT	TRANSVERSE	RMS	125	140	126	-	.0071	[illegible]	165	165	[illegible]	.0745	-	-	[illegible]	.0711	[illegible]	[illegible]
			MAX	385	548	598	-	335	[illegible]	348	325	285	250	-	-	165	165	139	[illegible]
		NORMAL	RMS	168	115	[illegible]	-	.0579	.0437	[illegible]	[illegible]	125	[illegible]	-	-	161	147	[illegible]	118
			MAX	465	425	346	-	220	165	225	225	465	365	-	-	575	540	[illegible]	[illegible]

TABLE 5 - SUMMARY OF MEASURED SHIP MOTIONS DURING WMEC 901 SEA TRIALS, MARCH 7, 1984

RUN NUMBER			24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
FIN CONDITION			ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF
RELATIVE HEADING			STBD BEAM	STBD BEAM	STBD BOW	STBD BOW	PORT BEAM	PORT BEAM	PORT QTR	PORT QTR	FOLLOWING	FOLLOWING	STBD QTR	STBD QTR	HEAD	HEAD	PORT BOW	PORT BOW
SHIP SPEED (kn)			15	15	15	15	17	18-16	15	15	19	19	17	18	16-15 12	12	12	12
OBSERVED WAVE HEIGHT (ft)			8	6	7	7	7	8	8	8	7	7	8	7	7	8	7	7
ROLL (degrees)		RMS	2.57	4.71	1.23	2.11	5.31	5.86	4.80	6.18	4.25	4.46	3.72	5.84	1.87	1.48	1.82	2.28
		MAX	18.0	24.3	10.9	11.7	25.8	30.8	18.4	23.6	10.1	15.1	15.2	18.9	3.94	5.97	5.07	7.32
PITCH (degrees)		RMS	1.61	1.64	2.17	2.28	1.30	1.42	1.26	1.32	1.42	1.32	1.16	1.28	2.27	2.34	1.77	1.88
		MAX	7.80	6.71	8.71	8.46	6.00	6.40	5.80	5.92	6.28	5.38	4.59	4.57	8.52	9.38	6.77	7.87
YAW (degrees)		RMS	2.98	2.13	[illegible]	3.64	2.29	3.58	14.5	13.3	2.73	2.58	2.54	2.18	1.40	1.28	1.66	1.11
		MAX	10.5	10.2	[illegible]	[illegible]	[illegible]	22.6	[illegible]	[illegible]	12.8	8.53	18.8	6.56	6.66	7.38	4.32	4.08
ACCELERATIONS (G's) CREW'S MESS	TRANSVERSE	RMS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	130	[illegible]	120	[illegible]	[illegible]	[illegible]	118	[illegible]	[illegible]	[illegible]	[illegible]
		MAX	[illegible]	511	[illegible]	[illegible]	471	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	NORMAL	RMS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PILOT HOUSE/CIC	TRANSVERSE	RMS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MAX	-	561	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-
	NORMAL	RMS	[illegible]	143	[illegible]	[illegible]	115	111	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	122	117
		MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	127	176	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HELO FLIGHT DECK	TRANSVERSE	RMS	[illegible]	115	[illegible]	[illegible]	130	137	113	131	[illegible]	[illegible]	[illegible]	128	[illegible]	[illegible]	[illegible]	[illegible]
		MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	217	[illegible]	[illegible]	[illegible]
	NORMAL	RMS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	172	[illegible]	[illegible]	[illegible]	221	[illegible]
COMMUNICATIONS CENTER	TRANSVERSE	RMS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	111	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	NORMAL	RMS	[illegible]	[illegible]	211	211	125	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MAX	[illegible]	561	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GUN MOUNT	TRANSVERSE	RMS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	111	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	101	[illegible]	[illegible]	[illegible]	[illegible]
		MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	175	175	[illegible]	[illegible]
	NORMAL	RMS	[illegible]	[illegible]	[illegible]	[illegible]	140	140	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	261	211	171	[illegible]
		MAX	[illegible]	[illegible]	[illegible]	575	530	[illegible]	225	215	[illegible]	175	[illegible]	[illegible]	1.07	[illegible]	[illegible]	[illegible]

TABLE 6 - SUMMARY OF MEASURED SHIP MOTIONS DURING WMEC 901 SEA TRIALS, MARCH 8, 1984

RUN NUMBER			[illegible]	41	42	43	44	[illegible]	[illegible]	47	[illegible]	[illegible]
FIN CONDITION			ON	ON	OFF	ON*	OFF	ON	ON	OFF	ON*	OFF
RELATIVE HEADING			FOLLOWING	STBD BEAM	STBD BEAM	STBD BEAM	STBD BEAM	STBD BEAM	PORT BEAM	PORT BEAM	PORT BEAM	PORT BEAM
SHIP SPEED (kts)			16	15	16	16	15	16	15	15	15	16
OBSERVED WAVE HEIGHT (ft)			7	7	7	6	6	6	6	6	6	5
ROLL (degrees)		RMS	3.06	2.22	5.00	2.03	5.05	2.16	1.92	3.71	1.05	3.94
		MAX	12.6	5.63	21.7	8.70	22.9	5.51	10.4	18.3	9.16	16.9
PITCH (degrees)		RMS	1.23	1.34	1.42	1.30	1.38	1.16	1.40	1.14	1.07	1.23
		MAX	6.13	6.27	6.31	6.76	5.86	5.63	6.26	6.65	4.94	6.32
YAW (degrees)		RMS	-	1.37	2.71	1.46	1.57	1.00	7.78	1.22	1.02	1.29
		MAX	-	4.06	11.5	6.57	6.53	8.53	36.9	3.96	3.24	5.16
ACCELERATIONS (G's): CREW'S MESS	TRANSVERSE	RMS	[illegible]	[illegible]	102	0725	123	0676	0661	0846	[illegible]	0827
		MAX	246	285	451	316	[illegible]	264	242	375	280	373
	NORMAL	RMS	0631	[illegible]	[illegible]	[illegible]	0863	0882	0774	[illegible]	0893	0772
		MAX	190	272	324	295	341	246	273	244	227	275
PILOT HOUSE CSC	TRANSVERSE	RMS	0461	0919	0482	[illegible]	0634	0437	[illegible]	0333	0213	[illegible]
		MAX	-	-	-	-	-	-	-	-	-	-
	NORMAL	RMS	0975	114	116	114	123	101	123	105	0803	115
		MAX	220	410	365	404	428	306	422	378	326	427
HELO FLIGHT DECK	TRANSVERSE	RMS	0831	0720	117	[illegible]	131	0840	0827	-	-	-
		MAX	306	300	520	338	529	382	283	-	-	-
	NORMAL	RMS	0916	0740	[illegible]	[illegible]	[illegible]	[illegible]	0861	-	-	-
		MAX	146	276	280	287	223	280	300	-	-	-
COMMUNICATIONS CENTER	TRANSVERSE	RMS	0652	0673	0807	[illegible]	103	0483	0581	-	-	-
		MAX	231	267	306	274	461	224	208	-	-	-
	NORMAL	RMS	0865	126	130	128	137	113	138	-	-	-
		MAX	257	441	306	442	464	307	472	-	-	-
GUN MOUNT	TRANSVERSE	RMS	[illegible]	0767	0822	0811	165	0483	0843	-	-	-
		MAX	378	300	316	286	375	155	536	-	-	-
	NORMAL	RMS	131	163	157	154	167	130	103	-	-	-
		MAX	520	[illegible]	475	546	525	465	825	-	-	-

*REDUCED FIN RATE

TABLE 7 - SUMMARY OF MEASURED SHIP MOTIONS DURING WMEC 901 SEA TRIALS, MARCH 13, 1984

RUN NUMBER			[illegible]	[illegible]
FIN CONDITION			OFF	ON**
RELATIVE HEADING			STBD QTR	STBD QTR
SHIP SPEED (kts)			15	15
OBSERVED WAVE HEIGHT (ft)			3	3
ROLL (degrees)		RMS	3.14	2.29
		MAX	8.92	7.14
PITCH (degrees)		RMS	0.740	.86
		MAX	3.59	3.39
YAW (degrees)		RMS	1.91	1.82
		MAX	8.10	7.85
ACCELERATIONS (G's) CREW'S MESS	TRANSVERSE	RMS	.065	.040
		MAX	.218	.157
	NORMAL	RMS	.041	[illegible]
		MAX	.128	.135
PILOT HOUSE CSC	TRANSVERSE	RMS	[illegible]	.046
		MAX	.223	.164
	NORMAL	RMS	[illegible]	.033
		MAX	[illegible]	.116
HELO FLIGHT DECK	TRANSVERSE	RMS	[illegible]	.065
		MAX	.282	.201
	NORMAL	RMS	[illegible]	[illegible]
		MAX	.101	[illegible]
COMMUNICATIONS CENTER	TRANSVERSE	RMS	.065	.043
		MAX	[illegible]	[illegible]
	NORMAL	RMS	[illegible]	[illegible]
		MAX	.131	.142
GUN MOUNT	TRANSVERSE	RMS	.065	.043
		MAX	.210	.165
	NORMAL	RMS	.043	.044
		MAX	[illegible]	.170

**MAXIMUM FIN ANGLE = ±20°

TABLE 8 - SUMMARY OF MEASURED SHIP MOTIONS DURING WMEC 901 SEA TRIALS, APRIL 10, 1984

			67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
RUN NUMBER			67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
FIN CONDITION			ON**	ON**	OFF	OFF	-	ON**	ON**	ON**	-	OFF	OFF	ON**	ON**	OFF	-	OFF	ON**	ON**	OFF
RELATIVE HEADING			HEAD	FOLLOWING	FOLLOWING	HEAD	-	STBD QTR	PORT BOW	PORT BOW	-	PORT BOW	STBD QTR	STBD BEAM	PORT BEAM	STBD BEAM	-	PORT BEAM	PORT BEAM	HEAD	HEAD
SHIP SPEED (kts)			10	10	10	10	0	10	10 16	13	0	13	13	13	13	13	0	13	13	13	13
OBSERVED WAVE HEIGHT (ft)			6	6	6	6	WAVE HEIGHT RUN	6	6	6	WAVE HEIGHT RUN	6	5	5	5	6	WAVE HEIGHT RUN	7	8	8	8
ROLL (degrees)		RMS	1.20	5.27	5.71	1.23		3.17	[illegible]	[illegible]		3.13	2.01	1.08	1.50	2.72		4.00	2.05	[illegible]	1.21
		MAX	—	16.4	19.4	5.04		10.3	4.46	6.27		12.2	10.4	7.94	8.32	11.0		20.2	13.1	4.28	5.30
PITCH (degrees)		RMS	1.91	1.18	1.08	1.84		745	1.02	1.21		746	1.22	922	[illegible]	1.07		1.85	[illegible]	1.50	1.61
		MAX	—	3.00	3.28	7.23		2.27	2.00	5.00		2.66	4.95	3.02	3.37	4.16		4.10	3.30	6.02	5.90
YAW (degrees)		RMS	1.30	6.44	4.06	985		8.71	881	1.02		1.00	11.9	1.33	2.34	7.02		-	-	-	1.28
		MAX	32.4	21.2	14.2	5.76		36.8	2.20	3.71		9.36	36.9	9.54	9.67	24.0		-	-	-	3.67
ACCELERATIONS (G's): CREW'S MESS	TRANSVERSE	RMS	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-
		MAX	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-
	NORMAL	RMS	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-
		MAX	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-
PILOT HOUSE CSC	TRANSVERSE	RMS	[illegible]	0861	[illegible]	[illegible]		0576	[illegible]	0333		[illegible]	0624	0335	[illegible]	0617		[illegible]	[illegible]	[illegible]	[illegible]
		MAX	—	276	324	152		[illegible]	194	172		[illegible]	[illegible]	[illegible]	194	[illegible]		303	[illegible]	116	[illegible]
	NORMAL	RMS	195	[illegible]	0279	191		0475	110	105		[illegible]	104	[illegible]	[illegible]	[illegible]		[illegible]	0725	[illegible]	[illegible]
		MAX	—	[illegible]	172	784		191	322	411		301	[illegible]	201	213	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
HELO FLIGHT DECK	TRANSVERSE	RMS	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-
		MAX	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-
	NORMAL	RMS	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-
		MAX	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-
COMMUNICATIONS CENTER	TRANSVERSE	RMS	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-
		MAX	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-
	NORMAL	RMS	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-
		MAX	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-
GUN MOUNT	TRANSVERSE	RMS	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-
		MAX	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-
	NORMAL	RMS	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-
		MAX	-	-	-	-		-	-	-		-	-	-	-	-		-	-	-	-

**MAXIMUM FIN ANGLE = ±20°

TABLE 9 - TABULATION OF DEPARTMENT PERFORMANCE ASSESSMENT FOR WMEC 901 SEA TRIAL, MARCH 6, 1984

RUN NUMBER	FIN CONDITION	RELATIVE HEADING	SHIP SPEED (knots)	OBSERVED WAVE HEIGHT (feet)	NUMBER OF CREW EVALUATED	CREW INCAPACITATED BY SICKNESS	CREW SICK BUT FUNCTIONING	ESTIMATED OVERALL SHIPBOARD DEGRADATION
8	ON	STBD QTR	16	14	89	6	37	51%
9	OFF	STBD QTR	16	14	109	5	55	52%
10	ON	FOLLOWING	19	14	109	5	52	49%
11	OFF	FOLLOWING	19	14	109	5	52	51%
12	ON	PORT QTR	15/19	13	110	5	52	47%
13	OFF	PORT QTR	19	8	105	6	50	47%
14	ON	PORT BEAM	19	8	106	6	51	44%
15	OFF	PORT BEAM	17	7	102	6	50	42%
16	ON	PORT BOW	17	7	85	5	30	40%
17	OFF	PORT BOW	17	6	85	5	32	39%
18	ON	HEAD	16	6	81	5	32	33%
19	OFF	HEAD	17	6	81	5	30	41%
20	ON	STBD BOW	19	6	81	5	32	40%
21	OFF	STBD BOW	19	6	85	5	31	34%
22	ON	STBD BEAM	19	6	85	5	30	33%
23	OFF	STBD BEAM	19	6	85	5	29	29%

TABLE 10 - TABULATION OF DEPARTMENT PERFORMANCE ASSESSMENT FOR WMEC 901 SEA TRIAL, MARCH 7, 1984

RUN NUMBER	FIN CONDITION	RELATIVE HEADING	SHIP SPEED (knots)	OBSERVED WAVE HEIGHT (feet)	NUMBER OF CREW EVALUATED	CREW INCAPACITATED BY SICKNESS	CREW SICK BUT FUNCTIONING	ESTIMATED OVERALL SHIPBOARD DEGRADATION
24	ON	STBD BEAM	15	6	73	5	30	37%
25	OFF	STBD BEAM	15	6	73	4	19	55%
26	ON	STBD BOW	15	7	102	9	28	50%
27	OFF	STBD BOW	15	7	94	8	28	55%
28	ON	PORT BEAM	17	7	95	6	29	46%
29	OFF	PORT BEAM	18/15	8	91	7	38	58%
30	ON	PORT QTR	15	8	92	7	33	61%
31	OFF	PORT QTR	15	8	86	7	30	55%
32	ON	FOLLOWING	19	7	90	6	32	43%
33	OFF	FOLLOWING	19	7	90	6	30	46%
34	ON	STBD QTR	17	8	89	6	29	46%
35	OFF	STBD QTR	18	7	82	4	24	37%
36	ON	HEAD	16/15/12	7	82	4	22	33%
37	OFF	HEAD	12	8	53	4	27	52%
38	ON	PORT BOW	12	7	52	4	27	58%
39	OFF	PORT BOW	12	7	52	3	28	58%

TABLE 11 - TABULATION OF COMMANDING OFFICER'S COMMENTS FROM PERFORMANCE ASSESSMENT QUESTIONNAIRE ON TEST DAYS 1 AND 2 OF FIRST SEA TRIAL

	RUN NUMBER	SHIP SPEED (knots)	RELATIVE HEADING	EXCESSIVE MOTION	DECK WETNESS	CREW PERFORMANCE PROBLEMS	EQUIPMENT PROBLEMS	COMFORTABLE RIDE	SPEED LIMITED*	MAINTAIN SPEED, COURSE?
MARCH 6th	8	16	STBD QTR	ROLL(>25°)	YES	YES			NO	NO
	9	16		ROLL(>25°)	YES	YES			NO	NO
	10	19	FOLLOWING					YES	NO	YES
	11	19						YES	NO	YES
	12	15/19	PORT QTR					YES	NO	YES
	13	19							NO	YES
	14	19	PORT BEAM			YES			NO	NO
	15	17		YAW		YES			NO	NO
	16	17	PORT BOW					YES	NO	YES
	17	17							NO	YES
	18	16	HEAD	PITCH	YES				NO	NO
	19	17		PITCH	YES				NO	
	20	19	STBD BOW					YES	NO	YES
	21	19							NO	YES
	23	19						YES	NO	YES
MARCH 7th	24	15	STBD BEAM		YES	YES			YES[1]	NO
	25	15				YES			YES[1]	NO
	26	15	STBD BOW	PITCH	EXTREME	YES	YES	NO	YES[1]	NO
	27	15		PITCH	EXTREME	YES			YES[1]	NO
	28	17	PORT BEAM	ROLL(>30°)	YES				NO	NO
	29	18/15		ROLL(40°)			YES		YES[2]	NO
	30	15	PORT QTR						NO	YES
	31	15							NO	YES
	32	19	FOLLOWING					YES	NO	YES
	33	19						YES	NO	YES
	34	17	STBD QTR					YES	NO	YES
	35	18						YES	NO	YES
	36	16/15/12	HEAD	PITCH	EXTREME	YES	YES		YES[3]	NO
	37	12		PITCH		YES	YES		YES[3]	NO
	38	12	PORT BOW						YES[2]	YES
	39	12							YES[2]	YES

*REASONS:

[1]Reduced visibility and heavy seas

[2]Excessive roll, "Low Level" alarms

[3]Excessive deck wetness, slamming, pitching, damage

APPENDIX A

CREW PERFORMANCE ASSESSMENT TECHNIQUES UTILIZED FOR THE USCGC BEAR TRIALS

Three individual methods for evaluating human factors parameters on the USCGC BEAR were employed during the seakeeping trial of March 1984. First, the DTNSRDC Performance Assessment Questionnaire II was distributed to officers, department heads, and selected crew members to elicit on-site degradation estimates of crew performance. Originally intended to query the entire crew, the questionnaire is made up of five sections. The first section addresses background information including susceptibility to seasickness and current medications. Section 2 is an initial assessment intended to determine the pre-octagon condition of the crew member. This is to help take into account the effects of such things as transit to the operations site prior to performing each octagon pattern. The next three sections are to be filled out after each segment (fins on/fins off) of each leg of the octagon. Section 3 is the individual crew member assessment where impediments to performing task(s) are noted and the details, including location, job, type and degree of impairment, are specified. The department heads rate their department's performance in Section 4 and the commanding officer's comments, including reasons, if any, for speed reduction, are made in Section 5. A sample DTNSRDC Performance Assessment Questionnaire II as used on the USCGC BEAR is presented in the back of this appendix.

Since the number of crew members aboard the BEAR prohibited the issue and collection of questionnaires to all, it was left primarily to the department heads to evaluate their respective crews, report performance impairment when it was observed, assess those job functions degraded, and forecast long range performance under conditions present during each leg. The commanding officer, too, was to assess the ship from his perspective, with primary emphasis on speed/heading evaluation and its long term effects. Ten selected crew members and three test personnel also filled out questionnaires during the sea trial.

The second human factors evaluation technique employed a motion-measuring backpack. With this backpack, angular velocities and linear accelerations of test personnel at the helicopter flight deck and in the crew's mess were measured during the specific legs of the octagons performed. This data will not be presented in this report but will be used to broaden the understanding of human response to ship

motions in a seaway, to aid in the development of human models for simulation purposes, and to ultimately become a standard tool for evaluating task performance degradation on future seakeeping trials.

Finally, a third assessment technique was employed that involved the human engineering experts of the Naval Biodynamics Laboratory (NBDL). This was the analysis of two specific locations designated as problem areas for crew members manning them. The Command Support Center (CSC) and the Communications Center were monitored by a representative of NBDL and questionnaires from that laboratory were distributed to crew members at these work stations. The results from this study are, in part, presented in Reference 10, "Human Factors Engineering Principles for Minimization of Adverse Ship Motion Effects: Theory and Practice" written by Drs. A. Bittner and J. Guignard, NBDL Reprot 84-R004 (June 1984). This report is forwarded to the USCG under separate cover.

PERFORMANCE ASSESSMENT QUESTIONNAIRE II

SHIP: ____________________
DATE: ____________________
to be filled out by DTNSRDC

SECTION 1: BACKGROUND

Name or Number and Rank: ______________________________

Length of Service: ______________________________

Average time at sea per year (%): ______________________________

Previous sea duty: Date ____________ Type of Ship ______________

I) From your past experience, how susceptible do you honestly feel you are to seasickness?

- ☐ very susceptible
- ☐ moderately
- ☐ slightly
- ☐ not susceptible
- ☐ no past experience

II) Do you usually take medication for seasickness?

- ☐ no
- ☐ yes

III) Are you currently suffering from an ear infection, cold, hay fever, or other ailment?

- ☐ no
- ☐ yes Specify: ______________________

IV) Do you currently suffer from dizziness, lack of balance, or nausea?

- ☐ no
- ☐ yes

V) Are you currently taking any medication?

- ☐ no
- ☐ yes Specify: ______________________

VI) Rate your present mental and physical condition by indicating your degree of impairment for the following categories:

	None	Slight	Moderate	Severe	Disabled
(a) Alertness	☐	☐	☐	☐	☐
(b) Physical fatigue	☐	☐	☐	☐	☐
(c) Seasickness	☐	☐	☐	☐	☐
(d) Injury	☐	☐	☐	☐	☐

PERFORMANCE ASSESSMENT QUESTIONNAIRE II

SHIP: ____________________
OCTAGON # ______________
to be filled out by DTNSRDC

SECTION 2: INITIAL ASSESSMENT

Name or Number and Rank: ____

1.) From your past experience, how susceptible do you honestly feel you are to seasickness?

- ☐ very susceptible
- ☐ moderately
- ☐ slightly
- ☐ not susceptible
- ☐ no past experience

2.) Are you currently taking any medication?

- ☐ no
- ☐ yes Specify: ______________________________

3.) Rate your present mental and physical condition by indicating your degree of impairment for the following categories:

	None	Slight	Moderate	Severe	Disabled
(a) Alertness	☐	☐	☐	☐	☐
(b) Physical fatigue	☐	☐	☐	☐	☐
(c) Seasickness	☐	☐	☐	☐	☐
(d) Injury	☐	☐	☐	☐	☐

PERFORMANCE ASSESSMENT QUESTIONNAIRE II

OCTAGON # ____________
LEG: ____________
to be filled out by DTNSRDC

SECTION 3: INDIVIDUAL ASSESSMENT

4.) What were you doing during this leg of the octagon? Briefly describe:

____

5.) Did you experience any difficulty in doing this task because of:

- ☐ your mental and/or physical condition(s)
- ☐ an equipment malfunction
- ☐ other:
- ☐ NO DIFFICULTY (Go to Question 6)

(a) If it was mental and/or physical, was it due to

- ☐ seasickness
- ☐ excessive ship motions (examples: stumbling, bracing yourself or having to hang on to something)
- ☐ fatigue
- ☐ ship-motion-related injury

(b) To what degree were you impaired?

- ☐ incapacitated
- ☐ significant
- ☐ moderate
- ☐ slight

6.) How would you rate your level of concentration?

- ☐ poor
- ☐ fair
- ☐ good

7.) What area of the ship were you in? ______________________________

8.) How would you rate this area's

(a) temperature:
- ☐ too hot
- ☐ comfortable
- ☐ too cold

(b) ventilation:
- ☐ poor
- ☐ fair
- ☐ good

(c) noise:
- ☐ loud
- ☐ moderate
- ☐ quiet

(d) fuel odor/exhaust:
- ☐ no
- ☐ yes

9.) Did you have a view of the sea and/or horizon?

- ☐ no
- ☐ yes

PERFORMANCE ASSESSMENT QUESTIONNAIRE II

OCTAGON # ____________
LEG: ____________
to be filled out by DTNSRDC

SECTION 4: DEPARTMENT ASSESSMENT

10.) How much difficulty did your department's crew members have in performing their duties?

- ☐ extreme
- ☐ moderate
- ☐ slight
- ☐ none

11.) Was the major cause of this difficulty due to

- ☐ seasickness?
- ☐ ship motions?
- ☐ crew fatigue?
- ☐ equipment failure?
- ☐ other?
- ☐ NO DIFFICULTY

12.) Assess your department's performance:

(a) There was a ____ % degradation in performance having to do primarily with

- ☐ the speed at which duties were accomplished.
- ☐ the quality and accuracy with which duties were performed.

(b) Out of ____ (# of crew in your department) there were ____ (# of crew) too sick to function, and _____ (# of crew) were sick but continued to function.

13.) What functions of your department, if any, were affected by poor crew performance?

(a) ______________________________

(b) ______________________________

(c) ______________________________

(d) ______________________________

14.) In your opinion, what would be the long-range forecast on the performance of your department, if this course and speed were to be maintained for a longer period of time?

____

____

____

____

PERFORMANCE ASSESSMENT QUESTIONNAIRE II

OCTAGON # ____________
LEG: ____________
to be filled out by DTNSRDC

SECTION 5: COMMANDING OFFICER'S ASSESSMENT

15.) What were the reasons that ship speed was limited at this heading?
List them in order of importance:

(a) ____________________
(b) ____________________
(c) ____________________
(d) ____________________

16.) If the speed has been limited on this leg, are there circumstances under which you would not reduce speed, and, if so, what are they?

____
____
____

17.) If speed was not limited on this leg, would you maintain this course and speed for an extended period of time? If so, for how long and with what effects?

____
____
____

18.) Comments:

APPENDIX B

COMPARISON OF SMP PREDICTIONS WITH MODEL EXPERIMENT DATA

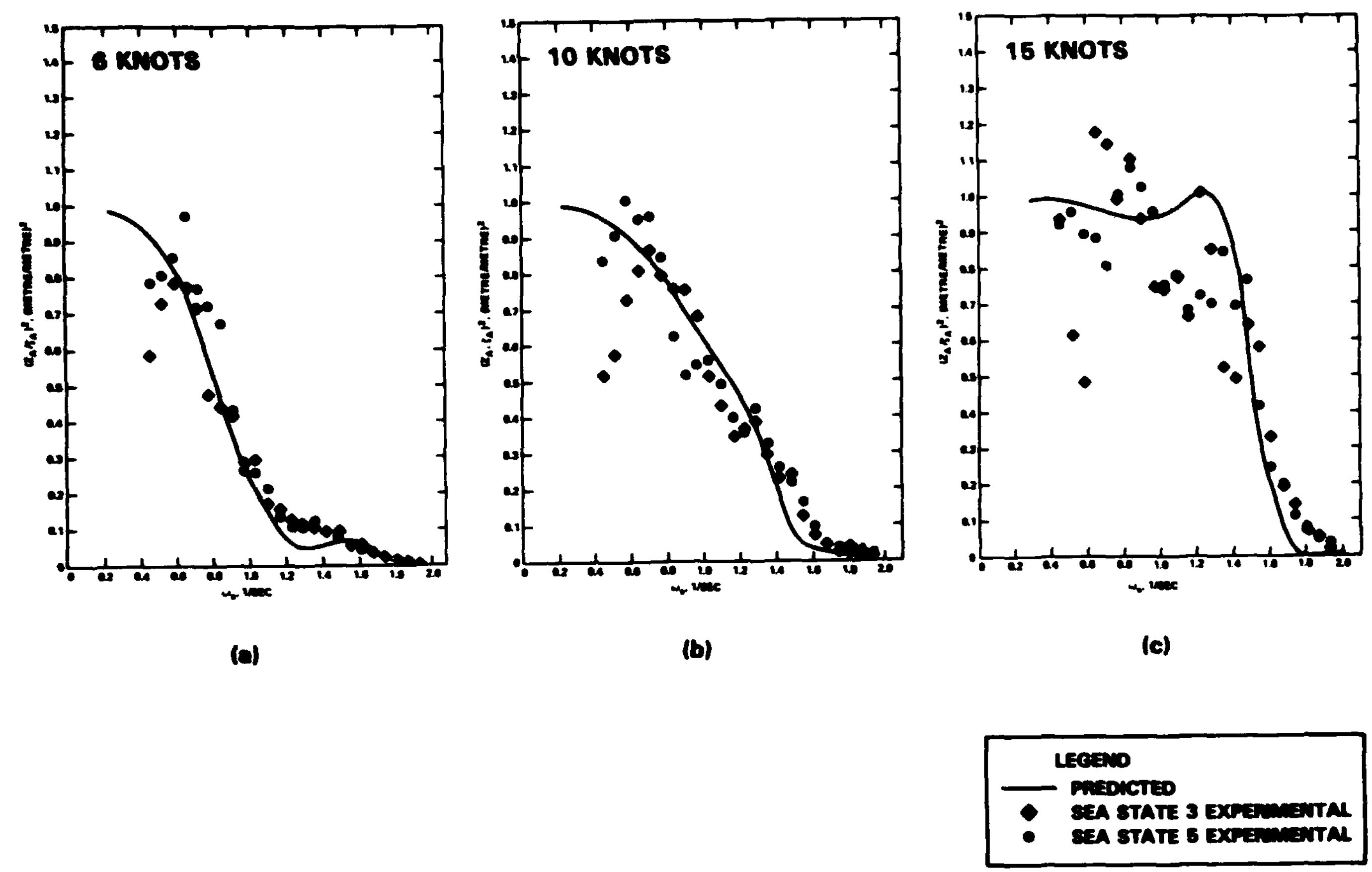


Figure B-1 - Comparison of Analytical and Model Test Heave Response Amplitude Operators

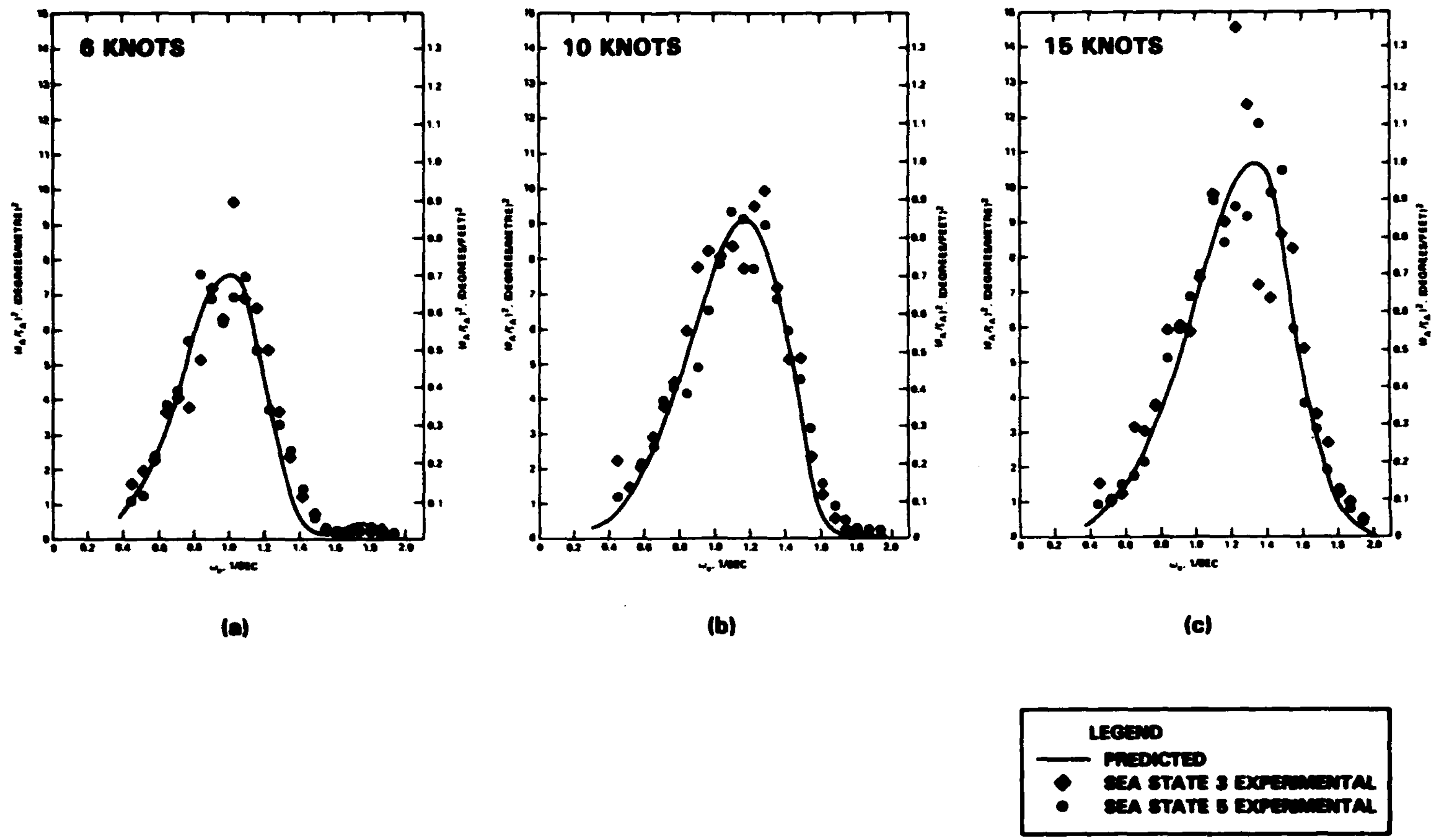


Figure B-2 - Comparison of Analytical and Model Test Pitch Response Amplitude Operators

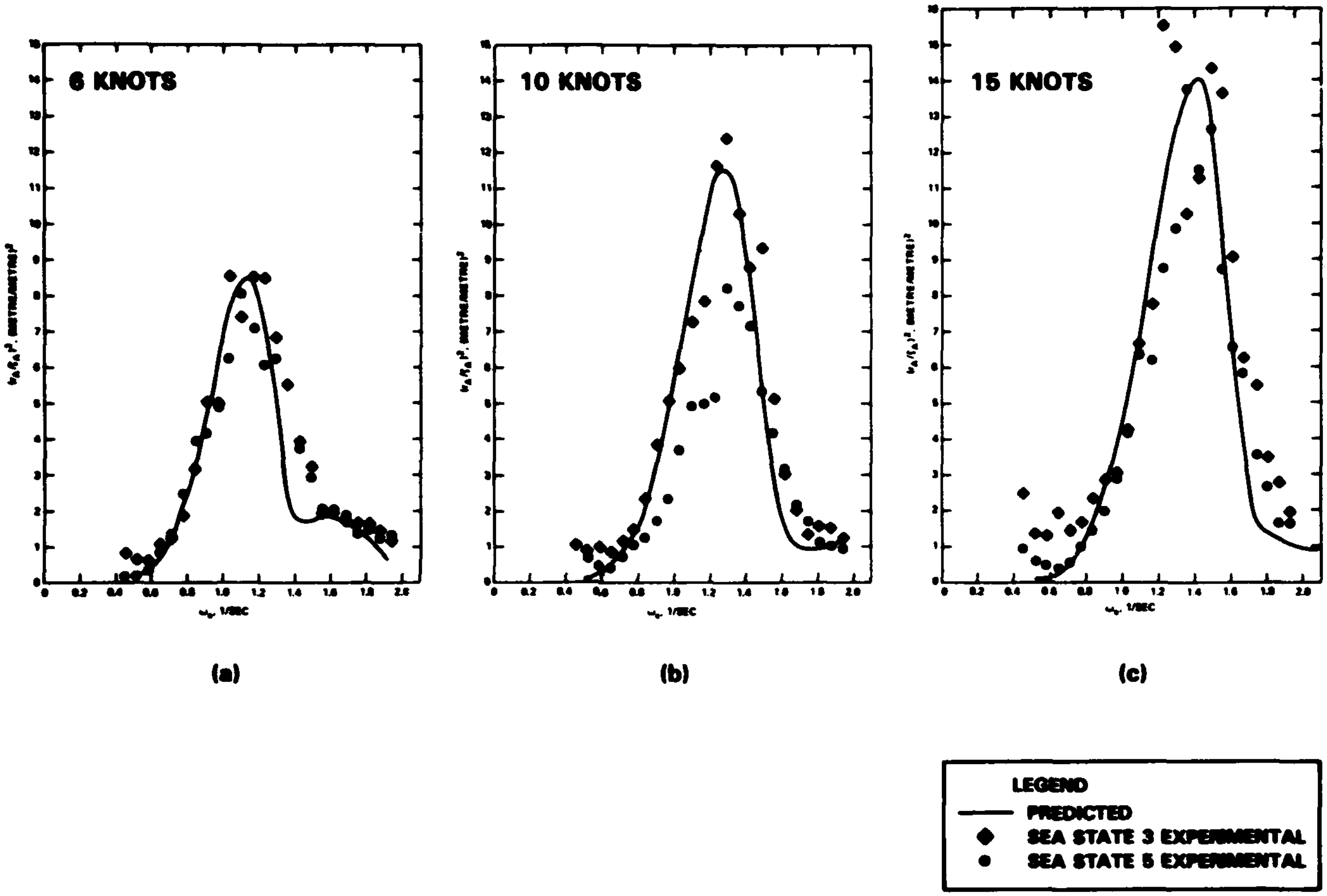


Figure B-3 - Comparison of Analytical and Model Test Relative Motion (Station 0) Response Amplitude Operators

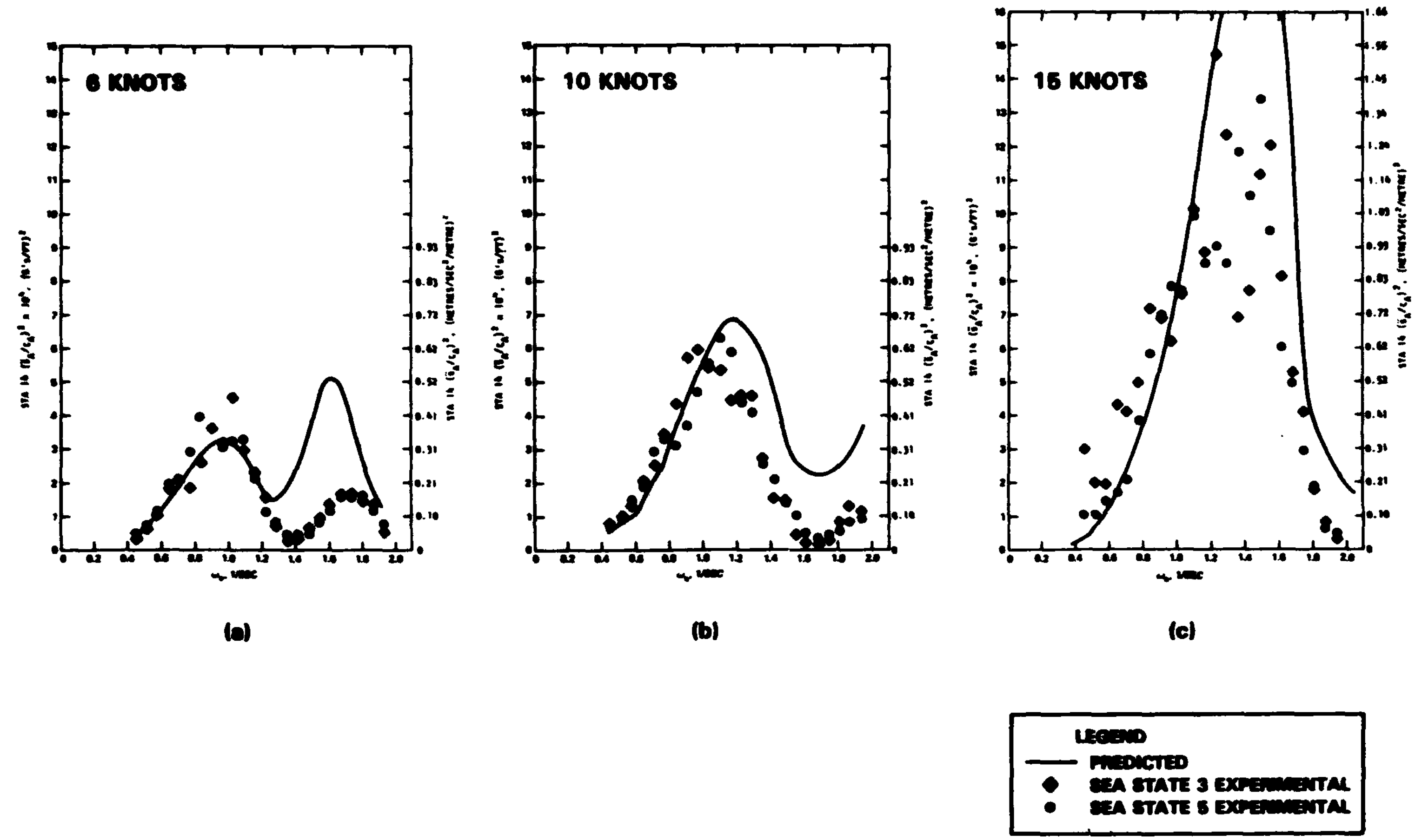


Figure B-4 - Comparison of Analytical and Model Test Vertical Acceleration (Station 14)
Response Amplitude Operators

TABLE B-1 - COMPARISON OF MODEL TEST RESULTS WITH SMP-GENERATED DATA

SIGNIFICANT WAVE HEIGHT

MEASUREMENT	SPEED*	5 FEET **				10 FEET	
		Model 5.5 sec	SMP 5 sec	SMP 7 sec	SMP 9 sec	Model 10.5 sec	SMP 11 sec
PITCH, degrees	6 knots	1.3	.5	1.2	2.7	2.7	3.1
	10 knots	1.4	.5	1.3	1.7	3.1	3.3
	15 knots	1.5	.4	1.4	1.8	3.2	3.4
HEAVE, feet	6 knots	1.1	.4	.9	1.4	3.5	3.5
	10 knots	1.3	.3	1.1	1.6	3.9	3.9
	15 knots	1.5	.3	1.3	2.0	4.1	4.4
RELATIVE MOTION @ STATION 0, feet	6 knots	4.8	3.1	4.9	4.9	7.8	8.2
	10 knots	5.1	2.8	5.3	5.5	8.0	9.4
	15 knots	5.8	2.7	5.4	6.0	9.3	10.4
VERTICAL ACCELERATION @ STATION 14, G's	6 knots	.031	.032	.039	.039	.065	.071
	10 knots	.037	.028	.047	.051	.084	.094
	15 knots	.056	.029	.071	.079	.112	.141

* SMP Speeds are 5, 10, and 15 knots

** Measured model test wave spectra demonstrates a broad energy range from about 9.5 seconds to 5 seconds (frequencies of 0.65/sec to 1.25/sec); Bretschneider wave spectra do not accurately model this broad range, so several spectral periods are given to cover the frequencies of significant energy.

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